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PRESIDENT'S MESSAGE

D. G. Malcolm

Having just returned from Louisville and the 5th Annual Conference and Convention of the American Institute of Industrial Engineers, I am filled with recollections and impressions of that most successful and stimulating meeting. I would be completely remiss, in this my first message to you, if I did not extend thanks to the Louisville Chapter for a job well-done. Not only will the proceedings of these sessions, which are to be published in the near future, be interesting reading, but also they will provide important contributions to the literature of Industrial Engineering.

It is extremely difficult to express adequate appreciation to your outgoing officers. Their efforts have resulted in marked growth and greatly improved stability of the AIIE as an engineering society during the past year. To Frank Groseclose and his officers, thanks, and you will not be permitted to "fadeaway."

Significant and encouraging to me was the fact that much of the thinking and discussion at the convention concerned the objectives of AIIE and Industrial Engineering as a profession. The two major themes which were evident are indicative of the maturing stature of our society.

1. A definite recognition of the responsibility and place of Industrial Engineering in the over-all engineering family.
2. The challenge to Industrial Engineering at its Crossroads.

These themes are interrelated, of course, but can be discussed separately. They may be thought of as our "extramural" and "intramural" problems respectively. In the first of the above themes, discussion centered about the fact and the implications that Industrial Engineers are first of all ENGINEERS. In this regard our responsibilities are two-fold. First, our aims and objectives both as a society and as individuals should be compatible, parallel and supplementary to those of the engineering profession. We should earnestly aspire, when ready and tested, to partake in the deliberations and responsibilities of the over-all professional engineering family. Secondly, due to our special emphasis on the humanic and economic modes of

(Continued on Page 22)

Editorial Comments--

The New System: "Job Enlargement"

By Dr. Robert N. Lehrer, Editor-in-Chief
Associate Professor of Industrial Engineering, Georgia Institute of Technology

It has been said that fleas have fleas, and the lesser fleas have even lesser fleas, ad infinitum. So it is with systems. Of course, we Americans are suckers for a sales pitch—and many systems are bought because of the sales pitch and our desire to find an easy way to cure all our ills and solve all our problems. However, it is a bit disconcerting to find that TIME magazine has contributed to the perpetuation of the increasing number of "panacea" systems in American Business and Industry.

I would like to quote several sections from a report carried in the Business section of TIME, April 12, 1954, page 100.[1]

> Workers find their enlarged jobs less monotonous, less fatiguing; they are absent less often, do less complaining, make fewer mistakes. With fewer setup men and inspectors around, foremen deal more directly with the workers, which cuts down sharply on misunderstanding and quarrels.

These statements are precisely correct. But, the report goes on to state:

> Today, as a result of job enlargement, morale in the department is higher and overtime has dropped 50%.

This is the point where I start to take issue with the report. The above statement is the start of another cure-all "panacea" system that will likely cause many a business man to pull out his hair. The increase in morale, decrease in overtime, and the later stated increase in production attributed to JOB ENLARGEMENT ignores the basic factors involved in the production or work situation. The results were obtained by manipulation of many factors that influence the overall work situation. Why not recognize the causative factors in the situation, and stop playing around with gimmicks? We want to design a work situation that maximizes the output and benefit to all concerned. This includes the worker, management and the owners of the plant or facility, the customer, and society. All the factors that influence the work situation, and they are numerous and complex, must be taken into consideration in order to intelligently design a favorable work situation. This cannot be accomplished by a *pot-pourri* technique. Not by JOB ENLARGEMENT or any other. But, let's find out more about JOB ENLARGEMENT. It does have some useful and interesting facets—if we recognize that it is not a cure-all. The TIME report continues:

> One of the axioms of U.S. business is that efficiency is increased by specialization. In keeping with the axiom, many jobs have been broken down into simple, repetitive tasks that workers can learn easily and perform swiftly. But such specialization has created a big problem: boredom. Bored workers are often poor workers with a high rate of absenteeism and spoilage of materials. To fight monotony, companies have tried various remedies (e.g., background music), although they have seldom questioned the deep-rooted belief that job specialization always lowers costs. But is such efficiency always efficient?
>
> Many businessmen are beginning to doubt it. They have found that in many operations there is a point where specialization ceases to pay. The savings in workers' movements is more than outweighed by the loss in interest and morale. As a result, some businesses are trying a radical new approach to specialization and the problem of monotony. The new system: "job enlargement."
>
> Job enlargement (a phrase coined by Yale's Human Relations Expert Charles R. Walker) was formally born in 1943. On a trip through International Business Machines Corp.'s plant at Endicott, N.Y., I.B.M. President (now Chairman) Thomas J. Watson spotted a young woman standing idly by a milling machine. She explained that she was waiting for the "machine inspector" (there was a "setup man," whose task it was to adjust the machine for each new operation, and an inspector, who okayed the adjustment). Actually, she was able to adjust the machine herself, but it was against the plant rules to do so.
>
> Watson decided to let her and other machine operators make their own adjustments, persuaded skeptical production executives to give the idea a trial. It worked. The idea of making jobs broader, instead of narrower, has since spread throughout the I.B.M. manufacturing plants in the U.S. . . .

[1] Courtesy TIME magazine; copyright Time, Inc., 1954.

The TIME report goes on to tell of the marvelous increases in production due to JOB ENLARGEMENT. However, it completely ignores the fundamental factors involved. It ignores the results of the now classic Western Electric-Hawthorne Study. It ignores the basic desires of individuals. It ignores the psychology of work. In fact, the only thing it didn't ignore was JOB ENLARGEMENT. TIME was greatly enamoured by the cure-all, "the new system —JOB ENLARGEMENT."

Well, what are some of the fundamental factors that are involved in JOB ENLARGEMENT? They are things that all alert Industrial Engineers recognize. Let me state a fundamental concept first.

> The main components of any work situation are men, materials and machines combined in a working environment. All factors that influence these main components must be considered. Not only must these factors be considered by themselves, but in combination, interaction, and as influenced by external forces of the work group, the organization, the economy, and the society of which the work situation is a part.

Technology is an important part of a productive work situation. But, the *human factor* is equally important but less understood. So, let me state a few specific points concerning the *human factor* in a working situation. (These are the extremely important points ignored in the TIME report).

- Each individual wants steady employment at reasonably high wages.
- Each individual wants to know that he has a chance to get ahead—if he cares to take advantage of the opportunities through diligence.
- Each individual wants to be treated with dignity and made to feel important.
- Each individual wants to be responsible—and know that his work amounts to something.
- Each individual is unique—an individual—and wants to be recognized as such.
- Each individual wants to belong—and work toward goals acceptable to his group.
- Each individual wants to know how he stands—with his boss and with his fellow workers. He wants to know when he is doing a good job, and equally important, he wants to know how he can do a better job.
- Each individual wants to share in the control of his destiny—both on the job and of.
- Each individual wants to be led—not pushed.
- Money looses its power of motivation when a certain minimum has been received—willingness, loyalty, etc. must be earned.

The various points mentioned above are only some of the more basic factors that determine what happens in a work situation. When principles are ignored—the work situation will not be as productive as it should be.

There is one thing about JOB ENLARGEMENT of which I am certain. JOB ENLARGEMENT, *per se*, is not a basic factor in the determination of how productive and satisfying a work situation might be. JOB ENLARGEMENT is a means to an end. Why give it more credit than it is due?

Well, is JOB ENLARGEMENT good? Sure, it *is* good. But, don't think for a moment that it's a cure-all. It is good only if the fundamental elements in the work situation are properly recognized. It is *NOT* a cure all to be used without considerable caution.

One final word of caution. When trying to maximize output while also maximizing the benefits of the worker(s), management and owner, customers and society, let's be more systematic, scientific and critical of the many gimmicks and techniques that have been touted as sure-fire systems. We should utilize controlled experimentation to evaluate the true results achieved by making a change in the work situation. All too frequently change causes increased interest and increased production due to things being different than they were. These benefits are false and temporary gains, soon to be lost. Let's make sure we are doing the right thing.

Writing and Reading

By Phil Carroll*
Professional Engineer

"The presentation might be unsatisfactory and the style objectionable because of the talking down to the reader impression that it gives." Thus sayeth the reviewer in describing one of my books. Referring to the same book, my host at a speaker's table said, "Phil, I certainly envy you your style of writing." I objected by saying, "It is not my style." "But you wrote the book didn't you?" was the Chairman's comeback. To that I replied, "Yes, but all I did was try to imitate Glenn Gardiner."

About a different book, another reviewer wrote "Mr. Carroll's style is a welcome relief from those of writers who believe that professional literature should be erudite and difficult. This volume is well written and quite readable."

Either of these reviewers may be right. It depends on how you look at readability. Naturally, I am concerned. They are my books. Writing a book is a chore. Before I ever started I was told, "You make about a nickel an hour for your efforts." This refers to technical writing — not best sellers like Cheaper by the Dozen.

If a "nickel an hour" is all you can make from technical writing, you have wasted your time if people won't read your report, article or book. If "there's no money in it," you must write to "contribute to the Profession" or to "put across your ideas" to your associates and your boss. From this line of reasoning, I conclude that you have to get people to read what you have written if you are to get a return on the time you have invested.

Why Be Difficult?

If your writing is too difficult to read, then people will put it aside. I hasten to grant that they may not even pick it up. I grant also that too many people will avoid learning about something new if they can avoid it.

You may be misguided as I was at the start. I said to the publisher, "What makes you think I can write a book?" His reply was, "Don't worry. If they want the information, they will dig it out."

If all our experiences have been in trying to "dig out information" from difficult writing, you may suppose that yours should be difficult to read. As Rudolph Flesch says, "Don't forget that everybody, including yourself, has only his own experience to think with."[1] Perhaps you continue in the same groove because you have heard that executives have large vocabularies. You may have concluded as Anthony Standen puts it, "Therefore learn ten new words every day and you will become an executive."[2]

Using simpler words is not the whole answer by any means. Our basic problem is to gain understanding. We hear about this every day with all the furor about "communications." Now you cannot assume that an easy-to-read communication will be understood. Nevertheless, I think it reasonable to say that the receiver of a communication will understand more if he reads it than if he doesn't.

Engineers Should Improve

The point is that I think engineers should acquire greater skill with words. Let me add, I am convinced that writing helps speaking. As I analyze it, the improvement in speaking comes from getting your words organized in ways that more correctly convey your meanings.

Much of our time is spent in explaining what we are trying to do. Perhaps I should say "selling" new ideas and new methods. In this important phase of our work, we can't get any place if we fail to "put over" our ideas. I'm convinced, too, that the higher you go in management positions, the more time you spend with words.

Don't try to put it off as so many do. They say, "I can't write an article" or "I can't make a speech." What they should say is, "I'm scared to death to try." The longer you put it off, the more apt you are to be in a poor state of preparedness at a crucial time.

The most pathetic sight I can remember was seeing an executive give a speech in accepting an Army-Navy "E" award during the war. His voice quavered. His delivery was halting. His words were rarely heard beyond the third row. My belief is that he gave the talk only because there was no escape from assuming the responsibility.

You Must Write

Whether you see the connection between writing and speaking is beside the point. You may be right in your view if you are thinking of "speaking" as delivering a paper before your professional society meeting. Remember however, that you are speaking every day when you are explaining some proposal to any listener.

Regardless, you do have to write. You cannot escape writing the occasional letter or report. Your work may demand that you prepare descriptions of technical processes or equipment. You may have to write someone to get action on a proposal you have made. In other instances, you are trying to explain what it is you have learned. Perhaps you may be called upon to write an article explaining your experiences for the benefit of your company's customers.

In any case, you cannot hope to get results unless the receiver will read what you have to say. That goes before the question, "Will he understand what I have written?" After that comes the question, "Will he take the action I recommend?"

Measuring Readability

Writing for easy reading is a "hot subject" currently. Like any new idea, some people object. Some think that to write for easy reading is to degrade the literature. Others are staunch advocates. I am one of the latter. For example, I was talking with an editor at McGraw-Hill sometime ago. He remarked, "I see that you are very enthused about the Flesch method." My reply was, "No—addicted."

Probably you know that Rudolph Flesch has worked out a formula for measuring readability. Robert Gunning has developed one for measuring "fog index." My belief is that both guides are very useful. On the other hand, there is more to writing than simplicity. This was brought out in an article in AMA "Management Review," December 1950 entitled "Is the Language of Business Doing Its Job."

This reports an experiment made by Fortune. Thirteen speeches were selected from 100 made by executives. These were divided into two piles. One contained five "lucid" speeches that did put across the ideas conveyed. The other included eight "fatuous" papers that fell short of attaining their purported goals. Both measured very much the same on a scale of readability. This is a clear indication that a quart may not be what you thought it was. It may be only 86 proof and poor tasting at that. Obviously, a measure by itself is not enough.

Learning the Hard Way

Please do not assume from what I have said that I think I am a writer. I am like most people. I insist upon learning the hard way. Let me prove this by giving you two examples of my own attempts—before and after.

BEFORE

On the other hand, the definition excludes many items of labor sometimes called production. Set up is one of this type that must be sepa-

*Author of Timestudy For Cost Control, Timestudy Fundamentals For Foremen, How to Chart Timestudy Data and How to Control Production Costs.

[1]Flesch, Rudolph, **Art of Clear Thinking**, p. 52, Harper and Brothers, New York 1951.

[2]Standen, Anthony, **Science Is a Sacred Cow**, p. 25, Dutton and Co., New York 1950.

rated because it does not occur for each piece. The more important exclusion is that of variations from normal, which occur when the material, equipment, and other conditions are not as they should be. Here, necessary extra time allowances are made to protect the operator. Looking backward from the standpoint of pieces shipped, the inclusion of the elements mentioned would destroy a true proportion by inflating the apparent production. Therefore a denominator for cost-control purposes must remain strictly proportional to good pieces produced. Otherwise, the results portrayed will not be in accordance with the facts.

AFTER

In contrast, the definition excludes many items of time often classed as productive. Set up is one of this type. It must be separated because it does not occur for each piece. Another is the host of "variations" from normal working conditions. These are the kinds of extra work that prompt the "rate setter" to use "temporary standards." These occur when the material, equipment and other conditions are not as they should be. The necessary extra time should be allowed to protect the operator. But these extra times do not represent extra production. Therefore, they must be separated from your measure of production labor.

Maybe this would be more clear if we looked at it backward from the standpoint of pieces shipped. Will the output be greater if we add in setups, extra work and waiting time? Certainly not. But in measuring output, it would appear as though we had increased it were we to add in any of these items. Any such indirect times that you may include will inflate your apparent production. And we all clearly understand inflation.

Organize Your Ideas

If you think that the "after" treatment is any better than the "before" example, you may want to read further. This change has come about as a result of studying about ten books on writing. Some of the ideas have taken root.

Like study in any field, chances are you learn the most from the first book you read. Others add new ideas but contain some repetition of the same fundamentals. More than that, I would assume that you "haven't time" to read the ten books I studied. Even so, you might be interested in learning some of the ideas I picked up from several of the authors.

In a book like Nelson's, "Writing The Technical Report," you would expect to find a great deal about how to organize your material. One point that he and other authors make is to put each idea on a separate 3 x 5 card. This allows you the greatest flexibility in collating your material by general subject matter.

Of course, his book contains many ideas about the need for proper sequence in your report. One of his points is illustrated by the oft-repeated, over-simplified outline of a "good speech." It goes something like, "Tell'em what your're going to tell 'em. Then tell 'em. Then tell 'em what you told 'em."

Another example is brought out by a mistake I made. An editor working on one of my books wrote, "On page 96, you mention five points. Where is the fifth one?" With this goes one of the most valuable suggestions I picked up. It has to do with the method of connecting your material together. This is clearly indicated in Nelson's book by means of diagrams.

Connect Your Ideas Together

Walter Campbell[3] comes as close as any author I have read to pointing out how to get continuity. He says there, "Since every sentence has, as it were, a head and a tail, it is generally wiser to have all the sentences in a given passage follow one another head to tail like a string of elephants in a parade, . . ."

Another means of connecting one sentence with another I explain as, "Make the object of the preceding sentence into the subject of the following sentence." This is similar to Campbell's idea of the head and the tail following each other in sequence.

You already know how to use the conjunction. "And" and "but" we learned about in grammar school. You use them to connect sentences and paragraphs. But there are many other connectives. Here are a few examples:

In short	after all	For instance	Even so
Just the same	In contrast	First of all	In someways
Another point	Yet it is	Conversely	As a result

These may be used to tie together ideas whether they be sentences or paragraphs.

Most of us do fairly well in connecting our sentences. We fail more often in bridging between paragraphs. For example Campbell says,[4] "In exposition it is customary to take up one point at a time and explain it in a paragraph. Thus each point is disposed of in turn. This breaking an expository composition into paragraph units makes it particularly necessary that these units be connected, not only by logic but by devices of style. That is what the 'overlapping paragraph' is for."

"When we say that two paragraphs "overlap" we mean simply that *some idea or phrase or word used in the last few lines of one paragraph is reintroduced or repeated in the first few lines of the next.*

Be Careful of Notes

When your ideas are collected, probably they will contain many notes. Here may be one stumbling block. Campbell says, "For the author almost invariably copies out the note instead of presenting the matter it contains freshly and from his own point of view in his own words. The result is a compilation of chunks of solid undigested fact, and these gobs of fact, lifted from the notebook, clog and check the flow and continuity of the work. Now continuity, as we discovered, is the basic principle of good writing. Without continuity we cannot hope to keep our reader reading, and all our effort is thrown away."[5]

Make It Interesting

Beyond these points that relate to what you write or say are others to keep in mind. One has to do with your order of presentation. I recall having read the manuscript of a paper sent me by a friend of mine. He wanted me to give it the blue pencil treatment. In the main, his paragraphs started off by setting the stage. He explained all that he thought was necessary before he made his point. I suggested that he invert his paragraphs and make his points first. His explanations could follow and become more interesting because the reader would know why they were there.

In this connection Campbell says,[6] "Often, indeed, the writer (of non-fiction) feels that his facts and ideas are so important that they should be able to stand alone, and he resents any emotional quality in his work as an intrusion and a distortion of his subject-matter. Just here is the rock on which so many earnest writers have been wrecked. They have been so intent upon their subject that they have neglected to take into account the capacities and demands of their readers." Later on he makes this point in terms of a rule. "A fact and a feeling in every sentence, or —if you prefer—an idea and an emotion in every sentence."

Similarly, Robert Gunning reports[7] a study of the writings of great authors of the past made by William Bayard Hale. These great writers used on the average 13 strong verbs and 4.5 adjectives per 100 words. And he goes on to quote Hale's statement that, "It is with a true instinct that language calls the part of speech which represents action, 'the verb'—the word."

What is Readable?

Then we come to the question of how readable is our paper or report. Gunning pointedly writes,[8] "The reader in each of us grumbles over the mass of difficult verbiage we are expected to read. But the writer in us turns to the typewriter or the stenographer with bland disregard of what makes reading easy." Later on he says,[9] "Wisdom goes on and on with simplicity. The keen mind is one that can absorb a complicated problem, then state it in simple direct terms that will transfer the idea quickly and accurately to the minds of others. Clarity of style cannot replace clarity of thought. But the two do go hand in hand."

You Can Measure Readability

To measure readability, Gunning uses what he calls "fog index." He places a fog index of 10 equivalent to an understanding of a sophomore grade in high school and to the readability of Time magazine. His fog index of 9 is equivalent to the understanding of a freshman in high school and the readability of Reader's Digest. He tested Reader's Digest for seven years and found that it has an average sentence length of 15

(Continued on Page 22)

[3] Campbell, Walter S., **Writing Non-Fiction**, Writer Inc., Boston 1944, p. 44.
[4] Loc Cit, p. 190.
[5] Loc Cit, p. 64.
[6] Loc Cit, p. 8.
[7] Gunning, Robert, **The Technique of Clear Writing**, McGraw-Hill Book Co., New York 1952, p. 101.
[8] Loc Cit, p. 4.
[9] Loc Cit, p. 9.

What Are the Specifications for an Effective System of Standard Data?

By Dr. William Gomberg

Director, Management Engineering Department, International Ladies' Garment Workers' Union

Based on addresses delivered to the Columbus, Ohio Chapter of AIIE, March 2, 1954, and the Fall meeting of the ASME, Rochester, New York, October 7, 1953.

The specifications for an effective system of standard data become meaningful only if we have a very clear concept of an effectiveness criterion. Let me illustrate what I mean.

Five different firms using five different pre-determined time systems in similar industries send representatives of their respective engineering departments to an engineering conference to present papers testifying to the successful application of their particular pre-determined time system to their particular set of industrial operations.

Now in spite of the fact that all of these five different pre-determined time systems will give different basic production standards for a work load under either a time work system of wage payment or an incentive wage payment plan, all five representatives testify that the particular system which they are using is yielding excellent results. The criterion of success is generally couched in amorphous language. We are informed that the management is happy and that the workers are happy with the new method.

Frankly, as a union representative let me add that I believe all five engineers are telling the truth. The criterion of effectiveness in these cases is actually a very crude empirical, pragmatic measure. Goods are turned out, workers continue to be paid, profits are made, merchandise is delivered.

This criterion is actually concealed however, by professional gobbledygook about the sounder scientific validity of the use of the new system of measuring work loads as against some older system of measuring work loads. What we have done in this case is confuse a scientific criterion with a pragmatic judgment.

What I wish to do in the remainder of the time at my disposal is to distinguish between these two concepts, the pragmatic concept and the scientific criterion. There is a confusion here between *value judgments* and the scientific method, and until we are able to clarify our own thinking it will be impossible to develop any criteria for an effective system of standard data. Let me first begin by comparing the use of macroscopic elemental standard data with an installation of pre-determined motion time methods within our own industry.

The New York Dress branch of our union utilizes a macroscopic system of standard data which remains in successful use after some 16 years of operation. It remains substantially the same as when first developed by a group of Industrial Engineers at that time. This system governs the piece rates negotiated on behalf of some 85,000 workers with their respective employers. Piece rates continue to be issued on continually changing styles. Work stoppage over piece rate disputes remain very rare. The industry has made the American woman the best dressed in the world at prices far below those paid elsewhere on the globe. In return workers have been able to earn a decent livelihood. In accordance with our pragmatic criterion the use of standard data in this case can be termed a success.

Now let us turn to two other situations. A large corset company in the midwest some years ago called in the Singer Manufacturing Company engineers to install the Singer Company's adaptation of Methods Time Measurement to the needle industry. Similarly, just a few months ago one of the largest manufacturers of robes in the country called in representatives of the Singer Sewing Machine Company for a similar installation. The experience of the representatives of the International Ladies' Garment Workers' Union with both of these installations have thus far been very happy ones.

However, before you start to cheer might I suggest that you find out why our experience was good. The mid-west factory required an extensive revision of methods which had become obsolete over the years. Can we credit Methods Time Measurement with this method improvement program or would we have not secured the same results with an older program proposed by Harold Maynard in his Operations Analysis or Allan Mogensen in his Work Simplification program or Ralph Barnes in his Motion Study outline? In short there is nothing unique that pre-determined motion time systems have brought to methods improvement except a set of doubtful numbers to go with the older technique.

Let us look into the use of these numbers. We assigned one of our most experienced representatives to "live" with this installation during the setting of the basic piece rates. He brought with him a mental picture of the identical operations performed elsewhere under similar conditions in our union factories making a similar line of merchandise. He took the initial list of times assigned to the different operations by the Singer engineer and running through the list made his demands for adjustments which were large in some cases and small in others. There was no constant relations between his figures and the engineer's figures. In every case agreement was reached on a final rate but, you see, the poor Singer engineer had to rationalize this bargaining technique within his own system.

Fortunately Methods Time Measurement does not define too exactly what average motions are rigidly required for any specific operation. By a judicious use of the latitude afforded him the engineer was able to present a set of time charts that suited the ritual of Methods Time Measurement and the collective bargaining requirements of the union.

It was a perfect example of the self demonstrating hypothesis, M.T.M. worked, that is, backwards. Under the circumstances we interposed no objection to the use of Methods Time Measurement in this factory. The manufacturer was told, in effect you are free to use whatever technique you choose to propose a piece rate. We, in turn, reserve to ourselves the right to choose or reject that rate on the basis of our time study techniques or empirical findings. If the ritual you have adopted compels you to go back and reset your motion description that's your problem, not ours.

A similar process is now in progress at the Woonsocket plant of the robe-manufacturer in which our union is represented by a staff member of the engineering department. There is no doubt in mind that we shall achieve a similarly satisfactory result.

What then would I define as the most valuable specification of this pre-determined motion time system that permits its use in collective bargaining? I would say that it is its very failure to achieve a rigid assignment of rates to specific categories: its very scientific weakness makes it a viable technique.

Of course where the methods time engineer is not challenged in a non-union situation, you no doubt could prove to me that the system also works. I will believe you. Given a despotism.

venal or benevolent, the subject must obey the master, and adjust his effort to the master's equity concept.

The important thing to remember, however, is that our criterion in both these cases is pragmatic. The system works. Our set of values by which we determine workability remains flexible for the engineer. His system can be imposed under a business despotism or politely adapted under an industrial democracy.

The macroscopic system of standard data works for the very same reason that the microscopic system of data works within a democratic frame of reference. If we were using Basic Motion Timestudy I suppose this process could be justified by Mr. Bailey's statement, ". . . experience in applying the techniques soon indicates that a high degree of judgment is required to interpret the use of this data to know where to interpolate or modify and what the results of such action will be. The orderly manner of applying the technique that is implied from the data has been misleading at times if not dangerous."[1]

After we've said this, where are we? Right back where we started from, I submit. Under our New York unit system the application of standard data lends us a tentative basis for piece rate. If the piece rate does not afford the workers an earning opportunity to which they are entitled, the men who apply the data feel no hesitation in modifying the rate. They feel no compulsion to go back to the data to twist the data to suit the new rate. The limitations of macroscopic elemental standard data are understood and are accepted.

Now let us ask ourselves what do both this macroscopic standard data system and the microscopic pre-determined motion time system share in common which makes them useful? I would answer: "enough residual flexibility to depart from answers called for by the basic data."

However, the ambition of every salesman of a pre-determined system of motion data is to secure uncritical acceptance of the final result, that is to take it outside the realm of collective bargaining. The detailed development of the possibility of such a set of data I can safely leave to the tender mercies of the representative of the academic profession.

Nevertheless let me summarize some of the requirements that an engineer imposes upon himself when he declares that he is ready to issue a pre-determined motion time system which will take work rate setting out of the realm of collective bargaining.

First and foremost, he must define a scientifically determined level of work at which workers ought to work. This calls for a double emphasis on the word *ought*. It is possible to secure a statistical distribution of the speeds at which workers are working. If we adequately define the criterion of stability of this distribution we then have an objective measure of what workers are doing.

Distributions, however, of what some engineer thinks workers ought to be doing like the current time study rating project of the S.A.M. are particularly meaningless. This is hardly the time and place for an exhaustive review of the S.A.M. rating project. I am in the course of making such an analysis. I believe it will prove that there is no rating method in sight which can give a scientific criterion of how much a worker ought to do. This amount of work a worker ought to do, like the amount of wages a worker ought to receive, is an equity concept and can be determined by no scientific means because it is outside the realm of the scientific method.

Once we are given a definite work level for a specific operation which both parties agree is equitable and we develop a hypothesis for extending this work level to related operations, then the scientific method provides useful criteria for testing the validity of our hypothesis in accordance with any precision requirements we care to impose upon the process.

Collective bargaining requirements would mean that we would need something in the neighborhood of plus or minus two and one-half per cent. This basic concept is necessary to any system of standard data, macroscopic or microscopic.

For the moment permit me to abandon my conviction that rating cannot be scientific and confine myself to the thinking more generally found in engineering circles. How "good" is the rating technique in securing times for the basic elements of a pre-determined motion time system? I should like to call the attention to a statistical psychologist who has analyzed the nature of the rating process. I think more is revealed by Kalman Lifson's small study than by the much heralded widely proclaimed S.A.M. study.

Kalman Lifson has been able to demonstrate that the judgments of the workers about their own performance were as reliable as the ratings of the time study men. Furthermore, there were real differences between the relative levels assigned the jobs by the raters and the relative levels assigned by the workers. Most significantly of all it was demonstrated that there was a marked change in the ratings of time study men after they had performed a job as against their rating of the job before they had performed it.[2]

Kinsler of the Oscar Mayer packing house corporation of Madison, Wisconsin in an unpublished paper demonstrates that the experienced time study men of his own corporation find it difficult to maintain consistency on the same operations filmed from one rating session to another.

I merely cite these examples to demonstrate how limited is the data of the S.A.M. project where single spot ratings of individual readings were taken. Given such chaos in the field of rating, how consistent, much less good, can be the fundamental building blocks out of which you are going to erect your pre-determined motion time system even if the trade unionist accepts the untenable assumption that rating can be scientific.

The next requirement is to demonstrate that fundamental units of the system are meaningful. That is, it is necessary to demonstrate that these subdivisions constitute an additive set. Abruzzi had demonstrated that the nature of the relationship among macroscopic elements is so complex that it varies from operator to operator. The whole question of the usefulness of even a simple elemental breakdown for any scientific purpose is thus raised, let alone a breakdown into fundamental units smaller than therbligs.

The only support I have seen for the additivity of sets of elemental data is a report of a very limited research project performed at the University of California. The very important restrictions the author imposes upon his results make one wonder how significant the whole experiment was. The conclusion state among other things that "The elimination, and as a consequence, the partwise treatment of motion elements do not change the collective times of the remaining elements provided:

a) the relative sequence of the elements remain unchanged.
b) the elimination does not destroy the basic geometric movement pattern of the task.[3]"

The relative weight of evidence for the additivity of motion elements advanced by Stilling is ove whelmed by the weight of evidence against any such possibility given by Abruzzi and Nadler. Until the supporters of motion study data can prove that such a subdivision of data is meaningful at all, there can be no serious attention given to data built upon a fundamental fallacy.

I have purposely omitted specifying what the nature of other correction factors to the basic data must be in order to secure a scientific basis for a predetermined motion time system. I am referring to matters like soundly tested allowances for interruption and allowances for fatigue. In the first place recent studies have raised the question of whether or not engineers ought to blank all of these allowances into the rating factor and make it a sort of pot pourri correction factor.

Meanwhile let me summarize as follows:

1. The effectiveness criterion can be defined in terms of a pragmatical-

[1] "Basic Motion Timestudy," by Gerald B. Bailey Proceedings S.A.M., April 1953, p. 91.

[2] Pages II and III, **A Psychological Approach to Rate Setting**, an unpublished Doctoral dissertation, by Kalman A. Lifson, Purdue University.

[3] **A Study of the Additive Properties of Motion Element Time**, by Donald Stilling, **Proceedings 5th Annual Industrial Engineering Institute, University of California, p. 43.**

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JOB EVALUATION—A Prerequisite to Wage Incentives

By James M. Galey

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Recently a friend of mine told me quite despairingly that his company's wage incentive plan was not operating as satisfactorily as had been anticipated. It had not increased production appreciably and had not performed the diverse miracles that his management had expected. "We can't understand it—we spent a lot of money setting up the program; it was given good internal publicity; and we held several training sessions to put it across. But it seems to have completely backfired . . employee dissatisfaction is evident."

Now I wonder if this is an isolated case, or does it happen more than most companies will admit?

I have a theory about such happenings which by the way is certainly not original. It is shared by many others in the field—academicians and practitioners alike. Not only is the theory not original, it is by no means new; but unfortunately, it has been overlooked in the "gold-rush" of the last 15 or so years, to the detriment of many wage incentive installations. This theory has to do with design and engineering versus installation and administration. To better discuss this theory, I will strike a rather crude analogy, but one which will emphasize the point.

I compare an industrial organization as we know it today to a precise, complicated machine. To build this machine each part must be engineered, and the assembly must be made in the best sequence. To keep our industrial machine functions. Much time and effort is spent that it be governed, that each component part be maintained properly, and that a certain amount of preventive maintenance be performed; that is, to subject it to a periodic overhaul.

Progressive managements have a systematic network of procedures, controls and stopgaps to govern the various administrative and productive functions. Investments are controlled, as are production quantities, sales, quality, accounts payable and receivable and other functions Much time and effort is spent designing and installing these functions, and their effectiveness is reviewed periodically. But in many organizations, even though the wage structure is quite properly installed and maintained, it is definitely *not* properly designed and engineered. This is particularly short-sighted in the face of two important developments of recent years: 1.) the increasing complexity of personnel administration, and 2.) the keen competition in industry for personnel of all types. Each of these two factors demand more than ever before an objectively engineered, properly installed and adequately maintained program of wage and salary administration.

Wage and salary administration is a rather all-inclusive term. In its full sense it usually involves the application of a wide variety of management tools such as job analysis and evaluation, wage surveys, employee evaluation, wage incentives, profit sharing and bonus plans, in order to arrive at an equitable distribution of the money allocated for wages and salaries. It is the general concensus that in order for individual compensation to be determined objectively, we must apply these tools with some system or pattern. Since we must have a firm foundation on which to build extra-financial compensation, it follows that the basic, relative worth of the job must be determined *before* consideration is given to individual effort or performance. Accepting this fact, we may evolve a system in our application of these management tools.

We can further systematize our approach by considering the general aspects of wage and salary administration as consisting of two distinct phases:

I. JOB WORTH

Those activities which are concerned with job content and basic job value, under conditions existing at the time of analysis. This phase of our work should furnish us answers to such questions as: What is the job, and what makes each job different from all others? How does the total difficulty and responsibility of each job compare with all other jobs in the organization? Considering this relative responsibility, what is the basic value to the organization of each job?

Job analysis, with the resultant job descriptions and specifications, gives us objective job facts which can be *evaluated* to determine the relative importance of each job to the organization. The basic value of the job is determined by considering the results of job evaluation. The basic value of the job is determined by considering the results of job evaluation in the light of such factors as prevailing community rates, economic conditions in the particular industry, government regulations (as applicable) and the results of collective bargaining. Determination of the basic job value is referred to as *job pricing* and is usually performed in conjunction with job evaluation.

II. EMPLOYEE WORTH

Those activities which determine individual compensation, after an incumbent has been placed on the job. Questions answered by this phase are: How well does each employee do his job? and finally, what exact dollar figure should each employee be paid?

How well the employee does his job may be determined by some form of employee *merit rating* and or *wage incentives*. The answer to the last question is found by relating the information gained by objective answers to all the preceding questions. I wouldn't be an engineer if I didn't try to formulize a relationship such as this, so we can express this end result of systematic wage and salary administration in the following form:

$$IC = f\ [BJV + (MR + IP_i) + K$$

where

IC = Individual Compensation

BJV = Basic Job Value, determined by tempering the results of job evaluation with information gained from wage survey, certain aspects of collective bargaining and legal considerations.

MR = Additional increment of pay given for performance on the job, measured by merit rating of the employee.

IP = Additional increment of pay given for performance on the job, measured by individual productivity under an incentive plan.

K = Additional increment of pay given under a bonus or profit sharing plan.

This formula is of course not one that allows you to put in values, turn the crank and get an answer, but it should remind you that merit pay, incentive earnings and other bonuses are after all, *incremental* monies that are added to, or related in some other way, to the basic job value. The factors within the brackets are ones used by the majority of organizations in which compensation is determined systematically. The parentheses enclose the factors which are dependent on individual effort or performance. The K factor in the foregoing equation is in many instances not a function of basic job value or individual performance, consequently it is not included within the brackets.

It is an unfortunate fact that many managements install a wage incentive plan after devoting little or no time to seeking objective answers to the questions posed by the *first* phase of wage and salary administration as here presented. Expected and actual individual productivity under an incentive plan is in most cases based on units of time and these units of time are converted to money, relative to the base rate. For this reason, base rates to a large extent determine the employees' earnings. If inequities exist in the basic rate structure, these inequities will be magnified proportionately by increased earnings, and magnification of a basically unsound rate structure is a prime reason for the failure of many wage incentive installations. A competent industrial engineer would not put a job on incentive without a thorough job analysis and subsequent standardization; yet this same engineer, after carefully analyzing, improving and standardizing a group of jobs, will superimpose an incentive plan on an unsound and inequitable structure of basic rates. And this action will in many cases be condoned by his management.

The precedent for this unsound action was set in the early days of Taylor's scientific management movement by persons too enamored with the possibilities of wage incentives to realize that this action could only result in a multiplication of existing inequities in the basic wage structure, with an accompanying increase in personnel problems. Incentives installed under these conditions generally failed to achieve the expected

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Work Sampling Studies:

GUIDES TO ANALYSIS AND ACCURACY CRITERIA

L. L. Sammet[1] and D. G. Malcolm[2]

In an earlier article, the authors have discussed developments in the use of the work-sampling technique (1).[3] The method was described as a means of estimating the proportion of time spent by a worker in a given work category from a series of "flash" or instantaneous observations. A growing list of applications of this method was noted, including the estimation of equipment and operator utilization percentages, work simplification analyses, the determination of element and production unit time requirements, studies of the flow pattern in materials handling, and studies of jobs involving team methods. Specific examples of the application of work sampling were presented, and procedures for obtaining observations were described.

Three aspects of the problem of statistical tests of reliability and analysis of the results of work-sampling measurements were noted as follows: 1. tests of reliability of the proportion derived from a given study; 2. tests of homogeneity of results from a series of studies made of a given job over a time period or analysis of variations observed in such studies; and 3. evaluation of the significance of work-sampling results as "forecasts."

Methods of Analysis in Relation to the Population Under Study

A review of recent reports on work sampling suggests some disagreement as to the methods appropriate for statistical analysis of work-sampling data (2) (3). Much of the difficulty appears to arise for lack of a clear concept of the population to which such tests are applied. To clarify this question, we note that for purposes of statistical analysis, we may define the continuum of events during an observation period as a "population." Such populations may take numerous forms, including the following:

1. Events in a single, continuous time period in which variations in the situation being observed are random.
2. Events in a single, continuous time period in which trend is, or may be, present.
3. Events in discontinuous time periods—for example, in situations that occur seasonally; in this case, the events occurring in a particular season might constitute a subpopulation, or strata, comparable to types 1 or 2.
4. Events in which a time sequence is not significant. For example, in studies of a given job performed under known variations in the work situation, the population may consist of certain values—for example, production unit times—associated with all possible variations in the work situation. The events occurring during the observation period for a particular variation in work situation studied may constitute a subpopulation such as described in types 1, 2, and 3.
5. Events related to a particular job performed in several different plants. In this case, the population may consist of certain values related to all jobs of this particular type in all plants. Again, subpopulations may be defined which consist of all events occurring with respect to this job in a particular time period in a given plant.

The above list could be greatly expanded, but it should illustrate adequately the kinds of problems encountered in applying statistical tests to work-sampling data.

In the simplest case, type 1, the probability of occurrence of a given event is constant throughout the observation period, and tests based on the binomial law are appropriate. When trend is, or may be, present as in type 2, different probabilities may be associated with particular sectors of the total observation period. Even so, if the population is regarded as a continuum containing a very large number of individual events—each of which has an equal opportunity of being observed — work-sampling data should yield an unbiased estimate of the average performance for the period, and tests of reliability based on an approximation to the binomial law should be applicable to the estimated average value.

The random observations required for strict application of the binomial law could be obtained with a system of randomly preselected observation times (4). On a less formal—although generally acceptable — basis, observations which closely approximate the type desired should result if the continuum of occurrences in a given work situation is subjected to a process of continuous, or systematic, sampling (1).[4]

The presence of trend during a given time period can be ascertained by making a series of separate studies, distributed over the time period. If appropriate tests indicate random variations between the results of the separate studies, the data may be pooled.[5] Depending on the circumstances, this may involve pooling all the *observations* from all the separate studies or pooling the *results*—for example, delay proportions or unit production times — of the separate studies. When time trends are present, regression analysis can be applied to the results of the individual work-sampling studies. This would provide an estimate of the amount of the time trend and a basis for tests of significance of this estimate.

In many situations, a consistent variation over time is not present, but there may be significant variations with respect to some other factor. This is the situation described above under types 4 and 5. In such cases, a series of work-sampling studies may be made, with each study related to a known—or selected—variation in the work situation. As in the preceding example, nonparametric tests, analysis of variance, or graphic analysis may be used to test the homogeneity of results from the separate studies. Depending on the indications of such tests, the separate studies may be pooled or the nature of the relationship to the known variation in work situation may be estimated.

To summarize the above, we note that statistical tests at two different levels have been described as follows: 1. simple tests, based on the binomial law and applied to data from individual work-sampling studies, or similar tests applied to the pooled observations from several studies if this procedure is indicated by a preliminary analysis and 2. tests of significance applied to the results of analysis of data in which the variation between separate studies is not random.

The ideas presented above perhaps can be made clearer by an illustration drawn

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[2]Staff Member, Operations Research Office, The Johns Hopkins University, Chevy Chase, Maryland, and Consultant to the Giannini Foundation of Agricultural Economics, University of California, Berkeley.

[3]Numbers in parenthesis pertain to references at the end of this paper.

[4]When properly conducted, the process of continuous, or systematic, sampling described in reference (1) possesses the following qualities: (1) a random start for the observation period in relation to any given work status; (2) unavoidable, although minor, variations in observation time per "round"; (3) an irregular — although not necessarily random—series of events to be observed or essentially cyclic observations with minor variations in the time period per cycle. Under these circumstances, no predisposition is evident to sample any given category of events; prior to the start of the study, any of the events in the continuum to be observed has an equal chance of appearing in the sample. Hence, an acceptable approximation to the type of observation desired should result.

Moreover, the use of the "informal" procedure would very likely provide a much larger sample—and possibly a more accurate estimate—for a given expenditure of observer time than an observation procedure based on randomly preselected observation times.

In the discussion that follows, we use the terms, "separate study" or "particular study," to describe the procurement of several hundred observations, closely spaced over a relatively short time period. These terms apply to either a systematic or randomized sample of this time period. A group of such studies made of a given situation is referred to as a "series of studies."

[5]The "population" in this case consists of the results of all possible studies during the total time period under observation. If a known distribution can be ascribed to this population, conventional tests of homogeneity can be made. Where the distribution is not known, nonparametric tests may be appropriate (see reference (5), Chapter 17). In some cases, the presence, or absence, of systematic variation may be demonstrated satisfactorily by simple, graphical analysis.

from recent studies of lettuce packing and shipping operations in California.[6] A particular work-measurement problem in this study was to determine the net productive time required to field pack a carton of lettuce, using different types of equipment. With one of the methods studied, the packing job is performed by a work group of eight packers who ride a mechanized packing unit. As this unit is driven through the field, lettuce—cut and trimmed by other crew members—is fed to the packers from a harvest strip 56 feet wide. Work-sampling observations on the jobs performed in this operation were made by an observer who followed the unit through the field strip, making repeated observation cycles through the crew in which one observation per cycle was obtained on each worker. Each observation was classified as to "working" or "not working" and there were several subclasses within each category. In addition, total cartons packed and total elapsed time per strip were recorded.[7]

Within the framework suggested previously, what statistical treatment of such data is appropriate? How shall the statistical population be defined? Are we justified in pooling work-sampling observations from all strips in a given field or from several fields? If we are primarily interested in net production times, is the proportion of working (or of not working) time itself of interest? Can conventional tests of proportions be applied to any segment of the data?

If all fields were perfectly uniform and there were no essential variations in the performance of different crews, pooling all observations and treating these data as a single set of random observations might be appropriate. This simplification, however, may not be warranted. Variation in the quality of lettuce is apparent between fields and within a given field. In fact, considerable variation frequently occurs in the quality of lettuce within a given strip. Performance factors with different crews also may vary. The presence of such variations tends to discourage the pooling of all observations unless suitable preliminary tests are satisfied.

Suppose we recognize that all sources of variation in the activity being measured cannot be singled out—to do so would involve treating each work-sampling observation individually—and that we consider a single harvest strip to be the minimum analytical segment. We might then argue that a process of systematic sampling applied to each strip yields an acceptable approximation to a random sample of activity in a particular strip. Proportions computed for a given strip give an estimate of average performance for that strip, and tests of reliability based on the binomial law may be applied. The standard error of estimate can be computed for proportions relating to each strip, and this can be used to obtain an interval estimate of the average unit production time for each strip. Note that at this level of analysis we have an approximation to the kind of population listed above as type 1.

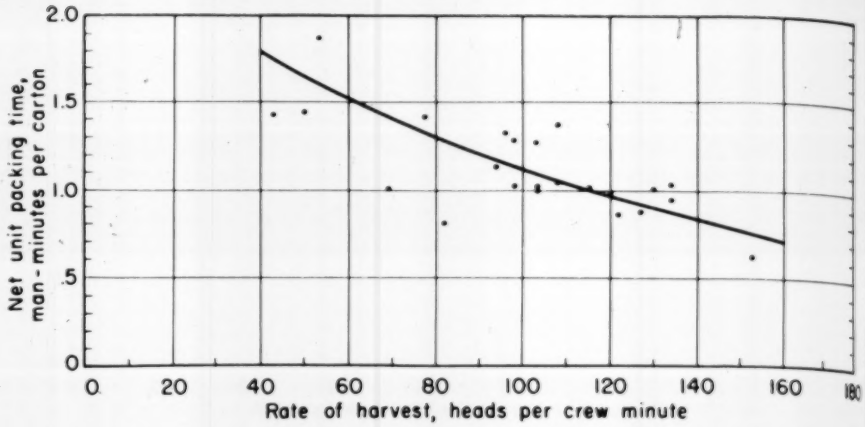

Figure 1. The effect of rate of harvest on net unit production time for field packing lettuce in cartons, using mechanized equipment.

An additional step in the analysis of unit production times in this example is illustrated in Figure 1. Each point in this chart represents the average net production time per carton in a particular harvest strip, plotted in relation to the observed rate of harvest. The regression line, fitted graphically to points based on studies of a series of harvest strips, indicates that net unit production time varies with rate of harvest.[8] This line obviously does not "explain" all of the variation in estimated unit production times as there is a noticeable scatter of points around the line. Part of this "unexplained" variation can be attributed to sampling errors in the work-sampling estimates, and part probably is due to the omission of significant variables from the analysis. For example, a multiple regression analysis relating unit production times to quality of lettuce and crew performance factor, as well as to rate of harvest, might greatly reduce the amount of "unexplained" variation in unit production times. If desired, the equation for the regression line in Figure 1 or for a multiple regression analysis could be obtained mathematically, and tests of significance could be applied to the regression coefficients. At this level of analysis, we are proceeding under the assumptions of our type 4 population.

If the simple graphical analysis illustrated in Figure 1—or more exhaustive regression or correlation analysis—had revealed no measurable trend or significant correlation of unit production times with other variables, a simple average of unit production times from all the separate studies would represent the most meaningful result of the analysis. If the analysis had been in terms of work-sampling proportions rather than unit production times, the absence of trend would suggest that an average of observed proportions for a given attribute would be appropriate, or evidence of random variation in the proportions observed for a given attribute in separate studies would indicate that all observations from all the separate studies might be pooled.[9] After pooling all observations we would proceed under the assumptions applying to population type 1.

While the above example could not possibly illustrate all of the problems one may encounter in the analysis of work-sampling data, it does highlight some of the points essential to this discussion. Note that we have illustrated our distinction between a "separate study," represented by a single point in Figure 1, and a "series of studies," represented by the entire group of points in Figure 1. Within the data comprising a series of studies, different statistical populations—with variations in analytical procedure—have been indicated. The problem of selecting the appropriate variable for analysis was illustrated. The desirability of performance ratings in some situations has been suggested. It has been shown that incorporation of some form of correlation framework or stratification in the sample design may significantly increase the amount of information obtained.

Reliability of Work-Sampling Proportions

To some extent, the preceding discussion is a digression from the principal objective of this paper, which is to consider the relatively narrow problem of statistical tests of reliability in situations where the binomial law is applicable. This digression seems desirable, however, in order to make clear the limitations of such tests with respect to work-sampling studies and to avoid the impression

[6]These studies were part of a cooperative project of the California Agricultural Experiment Station and the Agricultural Marketing Service, U. S. Department of Agriculture. This work was authorized under the Research and Marketing Act of 1946.

[7]For details as to method of data collection and computation of unit production times in this type of study, see reference (1).

[8]The variation in net unit packing time is attributed in part to variation in the pace of the packers and to a slight change in method of handling the lettuce as the rate of harvest varies.

[9]Note that wide variation in delay proportions in a study such as the above does not necessarily indicate inconsistent results or wide variation in the essential variable. This possibility is evident from the fact that crew size is fixed, while rate of harvest varies widely. In this situation, delay proportions would vary considerably, while relatively minor variations in unit production times might occur.

that an indiscriminate pooling of work-sampling observations is permissible or that tests of such pooled observations based on binomial law necessarily yield meaningful measures of reliability. It seems clear, however, that in the simplest case, tests of work-sampling proportions based on the binomial law can be applied directly. In more complex cases, such tests may be appropriate at certain levels of the analysis or may be applied to pooled data after preliminary tests have been satisfied.

In considering tests of proportions, we note that, in sampling for attributes, random observations follow the distribution of the binomial law. Computations based on this distribution are extremely cumbersome, however, and the normal distribution is frequently used. Results with the normal distribution closely approximate those obtained with the binomial distribution when the population proportion multiplied by the number of observations exceeds five (6). The normal distribution is used in the development that follows.

It is assumed that, for a given observation period, random observations can be secured. Suppose that of n such observations, n_π possess a given attribute. The proportion, $p = n_\pi / n$, then, is an unbiased estimate of the true proportion, π. The average value of p obtained from an infinitely large number of samples of size n is equal to π, and the variance of p is given by the equation:

$$\sigma_p^2 = \frac{\pi(1-\pi)}{n} \qquad (1)$$

For a given value of π and the value of p obtained from a particular sample of size n, we can state, with a probability α of being correct, that p does not differ from π by more than $t_\alpha \sigma_p$. Symbolically, this statement is:

$$P\left[-t_\alpha \sigma_p \leq p - \pi \leq t_\alpha \sigma_p\right] = \alpha \qquad (2)$$

in which t_α is found in a table of central areas under the normal curve for given values of α, the selected level of probability. Commonly used values of α and the related values of t_α are:

α	t_α
0.68	1.000
0.90	1.645
0.95	1.960
0.99	2.576

It is clear from equation (1) that, given a population proportion, π, and no limitation on sample size, the variance, σ_p^2, can be made as small as desired simply by increasing n. This means that, for a given level of probability, the term $t_\alpha \sigma_p$ in equation (2) may be reduced to any desired level, and we can substitute a preassigned admissible error, θ, so that equation (2) becomes:

$$P\left[-\theta \leq p - \pi \leq \theta\right] = \alpha$$

By setting $\sigma_p = \frac{\theta}{t_\alpha}$ we can express σ_p in terms of the preassigned values for admissible error and level of probability. Substituting for σ_p in equation (1), the solution for n is:

$$n = \frac{t_\alpha^2 \pi(1-\pi)}{\theta^2} \qquad (3)$$

From equation (3) it appears that the required sample size n increases directly with the probability level and inversely with the admissible error. For given values of t_α and θ, n increases from zero when $\pi = 1.0$ or zero, to a maximum value when $\pi = 1/2$. The size of sample required thus depends on the level of probability desired, the admissible error, and the proportion of the attribute being sampled.

Accuracy Criteria

The admissible error in the sample proportion is so chosen as to yield a desired —or agreed upon—accuracy in the final result. We may be interested, for example, in determining delay allowances on a piece-rate job, with the criterion of a maximum admissible error in the wage payment. Or we may be estimating delay time, or element times, for use in job analysis, with predetermined limits of absolute error in the time measurements. These limits may be based on judgment or may result from labor-management bargaining. When reflected in the admissible error in the sample proportions, they provide a criterion for determining the number of sampling observations consistent with the level of probability specified and the limit of admissible error desired in the final result.

In discussions of required sample size, one of two alternatives usually is considered. One procedure is to choose an admissible error, θ, that is constant regardless of the proportion being measured; the other is to specify the admissible error as $y\pi$, where y is a constant percentage of the proportion, π. The effect of these two criteria on the sample size required for a given level of accuracy may be indicated by substituting selected values for t_α, π, and the admissible error in equation (3). The results for $\theta = 0.05$, $y = 0.10$, and $t_\alpha = 1.960$ are shown graphically in Figure 2. Thus, with $\pi = 0.50$ and a constant admissible error, $\theta = 0.05$, n = 384. With the admissible error, 0.10π and $\pi = 0.50$, n is again 384. If, however, $\pi = 0.10$, the required n for $\theta = 0.05$ is 138, and the required n with an admissible error of 0.10π is 3,457.

It is evident in Figure 2 that, when $\pi = 0.50$, the required sample size is a maximum for $\theta = 0.05$ and a minimum for admissible error of $y\pi$. As π approaches zero, the required n also approaches zero when the admissible error is constant, but when the admissible error is $y\pi$, the required n approaches infinity as π approaches zero.

These contrasts in required sample size emphasize a practical aspect of the problem of specifying the error limit. If a constant absolute admissible error is selected, a level acceptable for relatively large proportions may seem excessive if the proportion is small. For example, an absolute admissible error, $\theta = 0.05$, may seem reasonable if we are sampling in a situation where $\pi = 0.95$, yet, seem excessive if π were small, say 0.05. We react in this manner even though these proportions are complementary as, for example, in a work-sampling study where the categories "working" and "not working" are $\pi_1 = 0.95$, "working," and $\pi_2 = 0.05$, "not working." The alternative of specifying the admissible error in relative terms, however, may lead to absurd sampling requirements for small proportions A uniform application of this criterion in work-sampling studies would lead to an extreme absolute accuracy, and a prohibitive sample size, for work elements comprising a small and perhaps inconsequential part of the total.

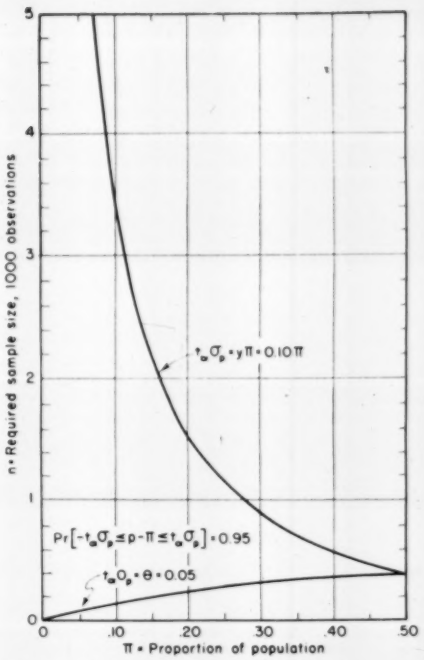

Figure 2. The effect of population proportion on number of work sampling observations required to secure preassigned limits of error in sample proportion under two criteria: (1) admissible error = 0.05 for all sample proportions and (2) admissible error = 0.10π.

Required Sample Size for a Given Level of Accuracy

Thus far, our discussion of reliability and the indications of required sample size for specified accuracy criteria given in Figure 2 have assumed knowledge of the true proportion, π. In a sampling problem, however, we have only an estimated value, p. If n is large, a satisfactory estimate of the variance of p may be obtained for a given sample of size n by substituting the estimated proportion p for π in equation (1). This provides means for probability statements concerning a given sample, as in equation (2), but as p is not known *a priori*, a direct solution for n in equation (1) is no longer possible. A solution for n in terms

of p and a constant admissible error, θ, is given by the equation[10]

$$n = \frac{t_\alpha^2 (\theta + p')(1 - \theta - p')}{\theta^2} \qquad (4)$$

in which $p' = p$ when $p \leq 1/2$, and $p' = (1 - p)$ when $p \geq 1/2$.

A graphic solution of equation (4) with $\alpha = 0.95$ and with selected values of θ is given in Figure 3. Note that these curves are symmetrical about $p' = 0.50$, that the required sample size for a given admissible error increases as θ becomes smaller, and that for each curve there is a minimum required n for $p = 0$ or 1.0.

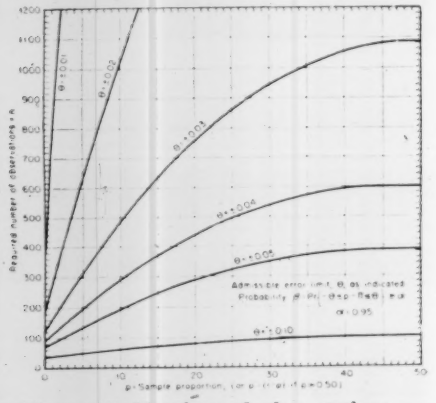

Figure 3. Number of observations required to obtain work-sampling proportions with given absolute limits of error and stated probability, $\alpha = 0.95$[11].

In applying Figure 3 to a work-sampling problem, an initial sample of size corresponding to $p' = 0$ is taken. A preliminary estimate of p' then is made and, if p' does not equal zero, or 1, a tentative value of the required n is obtained by entering Figure 3 at the observed value of p'. Additional observations are made and the process of "cut and try" continued until the desired convergence of values for θ, p', and n has been attained. In most situations, a few additional observations can be obtained with little cost so that a slight oversampling resulting from only occasional reference to the chart may be more practicable than an exact solution.

When the accuracy criterion is a percentage of the sample proportion, yp, the problem of estimating the required n for a given value of t_α becomes more complex than with a constant admissible error, for the effect of random variation in the sample proportion enters the admissible error criterion as well as the sample proportion. A solution for the required n based on a relative error criterion is not presented, although an approximate result indicating roughly the required sample size might be obtained by substituting $yp' = \theta$ in equation (4). By following the cut-and-try procedure of gradually increasing the sample size, a sample yielding the preassigned relative error, with the specified level of probability, could be secured.

Probable Error Limit with a Given Sample Size

Another possible criterion for work-sampling studies is to specify a constant sample size. The relationships between the error limit, θ, the observed proportion, p', and a given sample size, n, can be shown by transforming equation (4) to the following quadratic form,

$$\theta^2\left(\frac{n}{t_\alpha^2} + 1\right) + \theta(2p' - 1) - p'(1 - p') = 0 \qquad (5)$$

and solving for θ. A graphic solution showing the positive roots of this equation for selected values of n and p' and for $\alpha = 0.95$ is given in Figure 4. This diagram shows that, with sample size constant, the error limit decreases as p' becomes smaller.

In applying the criterion of a constant n to a work-sampling problem, a sample size might be selected which provides the desired absolute accuracy at a selected value of p'. The result is a "sliding scale" of absolute accuracy for other values of p', with the probable absolute error limit decreasing as p' becomes smaller and increasing as p' becomes larger. While there is no statistical justification for the scale of accuracy with different values of p' thus obtained, the procedure gives relatively greater absolute accuracy with small values of p' and represents a compromise between the criteria of constant absolute error and constant relative error. The specification of a constant n has the virtue of simplicity from the standpoint of the observer, and it would provide a firm and easily understood basis for agreement in labor-management negotiations.

An alternative application of Figure 4 would be to use it as a guide to the required sample size, given a predetermined absolute error limit, θ. By successive sampling and computation of p', one could gradually approach the value of n consistent with the observed p' and assigned value of θ.

Summary and Conclusions

In this and a preceding paper (1) numerous applications for the work-sampling method are described, and its use in measuring unit production and element times and in studies of team operations is illustrated. While the illustrations are drawn from studies of operations performed in packing and shipping agricultural products, the methods of data collection and analysis presented should be applicable to many industrial problems.

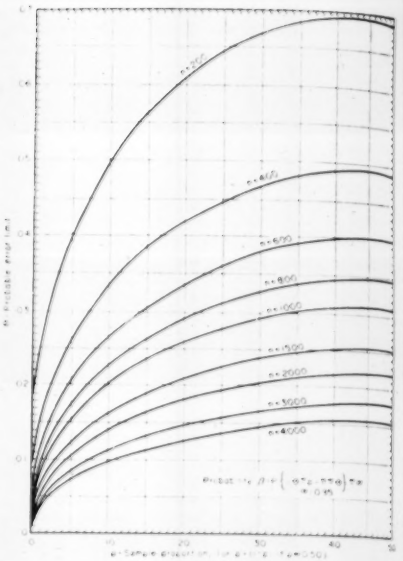

Figure 4. The effect of sample size and sample proportion on probable error limit in sample proportion. (Probability, $\alpha = 0.95$.)[12]

An observation technique based on systematic and continuous sampling is described. With qualifications appropriate to a particular sampling problem, this method may frequently be a useful alternative to a procedure of strictly random sampling. In fact, many situations may permit a much more rapid accumulation of observations with a systematic sampling procedure than would be possible with random sampling. Thus, systematic sampling might result in improved accuracy or greater economy. In some studies a sampling design involving some kind of stratification or correlation framework may be desirable.

Guides to the analysis of work-sam-

(Continued on Page 23)

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[10]For development of this equation, see reference (7). However, it should be noted here that the derivation of equation (4) is based on a confidence interval estimate of π such that

$$P[\pi_{1a} \leq \pi \leq \pi_{2a}] = \alpha$$

The terms π_{1a} and π_{2a} are functions of p' and are random variables. The interval is symmetrical—that is $(p' - \pi_{1a}) = (\pi_{2a} - p')$—only when $p' = 0.5$. When p' is smaller than 0.5, $(p' - \pi_{1a})$ is less than $(\pi_{2a} - p')$. In fact, when $p' = 0$, $\pi_{1a} = 0$, while $\pi_{2a} = \theta$, the amount of the admissable error. To obtain a conservative value for n, with the probability coverage specified, it is assumed that the true value of π corresponds with the particuar value within the confidence interval that requires the largest n. This criterion is satisfied by assuming $\pi = (p' + \theta)$ when $p' \leq (0.5 - \theta)$ and by assuming $\pi = 0.5$ when p' falls in the interval 0.5 to $(0.5 - \theta)$.

[11]This chart is based on the normal distribution. In the range where $np < 5$, use of the Poisson or binominal distribution would yield appreciably smaller values for n. Thus, some oversampling is indicated, although not to a serious degree.

[12]This chart is based on the normal distribution. In the range where $np < 5$, use of the Poisson or binominal distribution would yield appreciably smaller values for the probable error limit, θ.

The Functions of Industrial and Management Engineering —A Dynamic Approach to Their Definition

By Kurt H. Schaffir

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The repeated and continuing efforts in the current literature to define and delineate the area of industrial and management engineering attest to the difficulty of characterizing and differentiating this field with respect to other branches of engineering and to other areas of applied science not commonly associated with engineering.

The process of definition in general is composed of two steps—a statement regarding the category of things of which the subject is one, and the manner in which it is different from other subjects in this category. It is generally agreed that industrial engineering is an applied science. It is its differentiation which presents a problem. (See bibliography below)

Areas of applied science may be differentiated with respect to the areas of investigation covered. But it is clear that this is not possible here, since the industrial engineer shares the area of industrial operations with all other physical sciences, and has found it necessary in his work to draw extensively upon the techniques of the social sciences as well. Furthermore, the area of application of industrial engineering has come to encompass much more than industrial operations.

Most current efforts of definition have therefore aimed at differentiation along functional lines. On this basis, the industrial engineer may be said to be concerned with the analysis of a proposed product or service with regard to

1. Selection of methods and equipment,
2. Sequence of operations,
3. Layout of plant for most favorable flow,
4. Organization,
5. Control of quality, cost, operations, etc.,
6. Labor and personnel relations, etc.

Here, again, however, it becomes evident that none of these functions are essentially unique to industrial engineering. Furthermore, they fail to provide an underlying rationale on the basis of which it would be possible to establish criteria for what is and what is not industrial engineering. A better approach to this problem presents itself through a study of the evolution of industrial engineering functions.

Part of the answer may be found in the concept of industrial engineering as supplementary to the traditional branches of engineering; arising from the recognition that technological knowledge provides only a partial solution to problems of production operations. The following will deal with the development of the functions of industrial and management engineering based on this concept.

The Core of Scientific Management

From the historical point of view, the traditional activities of the industrial engineer are those concerned with the physical relationships of men, machines, and materials at the work place (*time and motion study*), spacial integration of unit operations in the production sequence (*materials handling and plant layout*) and the timing of operations (*production planning*).

The pursuit of these problems pointed up the need for greater knowledge and control of abilities and characteristics of the individual worker in relation to job requirements. This led to the development of *job evaluation, worker selection and training* methods, and motivation techniques (*wage and incentive systems*), which form the basis of what is now referred to in general terms as personnel relations.

The emergence of unionism and collective bargaining stimulated efforts in *work measurement* relative to establishment of equitable methods of compensation, associating industrial engineering more closely with labor relations in attempting to determine "a fair day's work for a fair day's pay."

Further Applications

The applicability of industrial engineering methods to other areas soon became evident. From the factory floor, the industrial engineer moved into the office, devising *methods, systems,* and *procedures* for the expeditious handling of clerical work. Engineering, accounting, distribution, procurement, etc., benefited from the use of these techniques.

Application to non-industrial activities, such as administration and operation of hospitals, transportation systems, governmental organizations, etc., have gradually materialized. A further step led to the analysis and design of tools and appliances in the home, and of special devices for the physically handicapped. The benefits to be derived from improved utilization of human and material resources in these areas are only beginning to be realized.

Personnel and Industrial Relations

The growing importance of personnel relations led to its establishment as a full-fledged and independent management function, concerned with all problems related to the employment of people, their compensation (both direct and indirect) and the relationship of the worker and his community to the employer.

Born of the union of engineering and psychology, personnel relations gave rise to further developments in *safety engineering* and *industrial health.* While dependent in its development on the efforts of workers in numerous different fields of study, it continues to afford a broad field for the application of industrial engineering principles and methods.

Organization

Because of the obvious inadequacy of our understanding of the processes of motivation and friction in work-groups, interest has focused increasingly on the nature of such groups and human associations in general. In his attempts to find answers to problems in this category, the industrial engineer has turned to the study of *organization* (group structure) and group dynamics, soliciting the help of sociology, social psychology, and anthropology; and to investigations of *communications* processes. Organization today has emerged as a formalized management function, embracing organization planning and executive development.

Prediction and Control

The increasing complexity of industrial operations brought with it the demand for greater predictability and control of product and operations. Statistical techniques, particularly as applied to *quality control, provided* an answer and were added to the industrial engineer's tool kit. This constituted the first major step in the continuing utilization of mathematical concepts of some complexity in the solution of every-day operating problems. Stimulated by specialized military needs during World War II, this general area of applied mathematics is recognized today under the name of *operations research.* Based largely on the concept of the "task-force" approach to problem solution where only the combined knowledge of a team of specialists in diverse fields can produce the answer, it has found successful application in market research, distribution, production control, purchasing, and various other areas of industrial operations.

The need for control—meaning effective action based on evaluation of on-going operations relative to a specified standard of performance—resulted in development of distinctive techniques for various administrative functions, such as *production control, cost control, inventory control; budgetary control,* etc. Current efforts are aimed at formulation of a methodology of management control for over-all planning and evaluation of performance. While most of these problems have long been the concern of the accountant, industrial engineering

has contributed much to the refinement of the methodology of their solution.

Industrial Economics

As a result of the introduction of new functions in management activities and the expansion of existing functions, the number of employees engaged in administrative work is constantly increasing in relation to the number of production workers. This rise of administrative overhead has focused increasing interest on fields of study concerned with the growth of fixed charges. Through elaboration of the concepts of the break-even point, budgetary control and standard costs, the industrial engineer has augmented the work of the cost accountant and economist in the field of *industrial economics*.

Currently, efforts in this area are aimed at uncovering the mechanisms which determine selection of alternate production methods and their relation to productivity (theory of production decisioning, input-output analysis,, etc.). Here, again, advanced mathematical methods find increased application (linear programming, econometrics).

Management Science

Perhaps the most important trend in the evolution of industrial engineering functions, somewhat in contrast to the above-described expansion into various specialized fields related to the production process, has been the continuing effort to integrate the fragments of knowledge accumulating in these various fields into a *cohesive conceptual framework* from the over-all viewpoint of *management*.

Recognition of the validity of the scientific method in practically every form of human enterprise has led to the gradual extension of industrial engineering into management engineering, clearly evident in today's curricula of industrial engineering education at the graduate level. Through the application of the scientific method to the management of human associations, and through integration of our knowledge of carrying out management's individual functions, industrial engineering today is actively engaged in the establishment of a Science of Management.

The above described evolution of new and expanded functions in industrial engineering is characteristic of a current trend in the development of science—namely the increasing interdependence of different disciplines in their common efforts to deal effectively with the complexities of modern society and technology. The boundaries between such fields as economics, business administration, industrial engineering, social science, etc., are fading (if indeed they were ever clearly defined), just as they are between physics, chemistry, biology, and so forth.

A Broad Definition

Broadly speaking, industrial engineering is concerned with the *analysis of the dynamic relationships between men, materials, machines, methods, and information, and the effective utilization of these elements of production in time and space.* As currently practiced, its functions may be categorized in brief as:

1. Work Measurement and Methods.
2. Analysis of work flow.
3. Matching of Workers and Jobs.
4. Compensation Systems.
5. Organization and Communication.
6. Prediction and Control.
7. Economics.

Specifically, this covers such fields as:

1. Time and motion study, methods, systems, and procedures, standardization, etc.
2. Layout and materials handling, production planning, etc.
3. Job evaluation, selection, training, evaluation, compensation, etc.
4. Wage and salary administration, design of incentives, etc.
5. Organization planning, executive development, communications, etc.
6. Forecasting, market research, quality, production, inventory, sales, budgetary and other management controls.
7. Break-even analysis, input-output analysis, etc.

This list is not intended to be exhaustive. The concept of industrial engineering has been continuously broadening. The definition of industrial engineering as an applied science, supplementary to and integrative with respect to other branches of science related to the management of human associations, must of necessity be dynamic in nature. It must keep pace with our growing understanding of social and technological processes, continuously alert to new techniques on one hand, and new applications on the other.

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JOB EVALUATION—

(Continued from Page 8)

and desired result; however in a few cases some degree of success was attained.

Present day collective bargaining to some extent has had a stabilizing effect on rate structures, so that the number of organizations which consider their incentive programs successful has increased. Yet the point which still is frequently overlooked is: an incentive program alone, no matter how carefully installed and administered, will never develop and *maintain* the full productive potential of the work force. A wage incentive plan is not a "gimmick" to be applied singly (and hopefully); rather, the whole wage payment plan must be carefully designed and engineered so as to have a firm footing for incentive payment. The foundation on which to build a successful program of wage incentives is a defensible structure of relativity and equitable pricing of the jobs, brought about by sound job evaluation.

BOOK REVIEWS

"Materials and Processes"
by James F. Young
John Wiley & Sons, Inc.
New York, Revised Edition, 1954
1074 Pages, $8.50

This book is one of a series prepared in the interest of the General Electric Educational Programs. These books have been well received, for they are well written and profusely illustrated. Mr. Young's revised edition has been greatly expanded to give a reasonably complete and up-to-date coverage of materials and processes from the engineer's point of view. The engineering viewpoint is applied to the important fields of metallic and non-metallic materials and manufacturing processes to provide information for the design, production and control of products.

"Proceedings, Seventeenth Annual National Time and Motion Study and Management Clinic"
The Industrial Management Society
35 East Wacker Drive, Chicago 1
1954, 163 Pages, $4.00

The **Proceedings** of this annual meeting sponsored by I.M.S. is a complete reproduction of all the speeches (with illustrations) and discussions from the three day meeting. The subjects covered include Times Standards, Incentive Systems, Work Simplification, Job Evaluation, Controls, Material Flow, Industrial Relations and Management Subjects. Every Industrial Engineer will find it well worth his while to read this volume.

Formulating A Theory Of Work Methods

By Adam Abruzzi

Associate Professor of Industrial Engineering, Stevens Institute of Technology

The "One Best Way" Approach

The orthodox point of view regarding standardizing work methods originated in the writings of F. W. Taylor. This point of view postulates that there exists a unique maximal method of performing an industrial operation in which one must "eliminate all false movements, slow movements and useless movements (and) . . . collect into one series the quickest and best movements as well as the best implements."[1]

This point of view was later adopted by F. B. Gilbreth as a base for developing the field of motion study and methods analysis. As it was for Taylor, Gilbreth's objective was to develop a "one best way" of performing an industrial operation.[2] Although the observation and analytic procedures have undergone considerable refinement, the "one best way" is also the primary objective of contemporary practitioners in this field. The "one best way" is usually described as the most economical way of performing an operation in terms of the number and the type of motions required. In practice, it is considered to be the method involving the fastest time consistent with the results achieved by skilled workers, using a superior sequence of motions from which all unproductive movements are eliminated.

In evaluating the results of a motion study, liberal use is made of the rules of "motion economy," also largely developed by Gilbreth. Twenty-two rules are usually considered and they fall into three groups:

(1) those relating to the use of the human body;
(2) those relating to the work place;
(3) those relating to the design of tools and equipment.[3]

A typical example is the statement that body motions should be confined to the lowest possible classification, under the assumption that this will automatically reduce the time and effort required. According to this assumption, for example, a motion performed by the wrist and fingers would be changed to a simple finger motion whenever possible.

Although not the primary subject of this paper, the standard-data concept so widely popular in current work measurement practice should also be summarized briefly. This concept was also originally developed by Taylor who proposed that time records be obtained for groups of elementary movements.[4] Then when the proper series of motions for a given operation has been determined, the time data for the movements involved would be added to find the proper time for performing that operation.

As this proposal suggests, the standard-data concept is based on the prior acceptance of the "one best way" concept; it essentially extends the latter to the area of time measurement. Consequently, the validity of these two concepts can be determined simultaneously in terms of their common assumptions. Since many of these assumptions can be tested most conveniently in terms of a time parameter, the "one best way" concept can be evaluated implicitly during an evaluation of the standard-data concept.[5]

The most important common assumptions of the two concepts are that:

(1) a descriptive definition of motions (and of groups of motions) is sufficient to identify them uniquely;
(2) only a limited number of so-called fundamental motions exist;
(3) these motions are independent of one another, and of the operation cycle in which they are used;
(4) the properties of these motions including the time required to perform them, are essentially constant and, hence, independent of the worker;
(5) the "one best way" should be free of any unproductive motions;
(6) the "one best way" (and the time values involved) can be abstracted largely on a subjective basis by the observer using an extremely limited number of observations on arbitrarily selected workers.

Critical Views

The "one best way" approach can successfully be challenged even on an *a priori* basis. Thus, a "best" method from a psychological standpoint would not necessarily be the best from a technical standpoint. To express this in more specific terms, it is impossible to find a unique solution of a work methods problem that is a maximum simultaneously with respect to all the independent variables. Obtaining a maximum with respect to a single independent variable invariably means accepting less than a maximum with respect to other independent variables. What can be obtained is a restricted maximum or an *optimal* solution, subject to the requirements imposed by jointly considering all the independent variables involved. The result is, then, that the "one best way" concept is essentially a formal conception defining an abstract situation under idealized conditions.

Essentially the same conclusion has been reached by numerous critical students on the basis of empirical observation. More than two decades ago, for example, E. Farmer pointed out that the motion patterns of different workers differ substantially, even among workers in the same skill class.[6] This finding, among others, prompted Farmer to make the following comment: "it seems highly doubtful whether various movements, taken from different groups of movements, merely on account of their taking a shorter time to perform than similar movements in other groups, can be combined into an independent group which would yield results as satisfactory as the original groups."

The same viewpoint is taken by more recent observers such as A. B. Brown, who finds that the "one best way" is an illusion because workers have different abilities and needs.[7] E. E. Ghiselli and C. W. Brown likewise criticize the "one best way" approach on the ground that a given method may be optimal for most workers, but not best for all workers.[8]

J. Gillespie also denounces the "one best way" concept.[9] Thus, he "denies that a real motion pattern is equivalent to a motion pattern built up of bits of motion." The whole approach, he adds, "is ridiculously inaccurate, dangerous in application, ignores work psychology and is bad physiology."

H. Davidson makes some cogent remarks on the subject as part of an incisive survey of the entire field of work measurement.[10] He says that "construction of theoretical motion patterns may be an interesting activity, even though there may be no living human who is physiologically or anatomically capable of performing the particular series." On the basis of certain experiments on relatively simple tasks, he adds that movements are not independent but are related to other movements which precede or follow them.

The Role of Purposive Human Behavior

As this critical material suggests, the problem in work measurement and, more specifically, work methods are complicated by the presence of a crucial non-physical component. This component is purposive human behavior which cannot readily be described by deterministic or even statistical laws and which is distinguished by the fact that it involves planning and organization. It is unique to the individual who adjusts his behavior in an essentially non-random manner to fit his capabilities, needs, and purposes according to past experience and in anticipation of future events.

In a sense, this behavior is analagous to that of a mechanical feedback system in which current performance is also modified in terms of past events. However, this analogy cannot be carried too far. All non-human feedback mechanisms thus far developed have built-in restrictions on their behavior, one of the most important of which is that it is well defined in a statistical sense. In particular, the behavior of such systems can be predicted within a limited range, and any departure from expected behavior can be classified as a random departure.

On the other hand, human purposive

behavior cannot be characterized in such a simple manner. Thus, a worker's behavior may be the product of a large number of conflicting, complementary, and interacting purposes, when he acts variously as an individual, as a member of a trade union, as a member of an informal "work team," and so forth. Moreover, the presence and relative importance of any one of these purposes does not lead to a fixed or even a precisely predictable component of his behavior. Rather, they are continually shifting in importance and emphasis according to the immediate situation. This situation is the result of similar purposive behavior on the part of other members of the industrial society as well as his own previous behavior.

Describing the implications of this behavior with respect to work methods is one of the major objectives of his paper. The experimental findings involved have been abstracted from detailed studies described in *Work Measurement: New Principles and Procedures.* [1]

Overall Attitudes and Behavior

A central finding of these studies was that the formal as well as the informal attitudes and behavior of workers has a decisive but non-constant effect on their performance at the workplace. A particularly significant component is the formal and informal bargaining attitudes and behavior associated with production-rate problems. This bargaining component is largely the result of the usual intimate relation that currently exists between wage payment and production rates.

This, leads in turn, to a fairly large number of associated attitudes and behavior, two of the more important being:

(1) The conscious and/or unconscious tendency of workers to give biased performances before and during the observation process as a purposive reaction to the potential effect of this process on their vocational welfare.

(2) The almost universal regulation of output by workers and worker groups after the process of observation. This is a stronger and permanent purposive reaction to the process of observation and its ultimate potential effect on their vocational welfare. Regulation of output, moreover, depends in type and in degree on the individual worker and varies according to age, sex, political background, and so forth. The result is that there exists a set of purposive variables which are essentially fixed for a given worker, but which vary from group to group and factory to factory.

More Specific Effects

At the operation unit or cycle level, it was found that purposive behavior exhibits itself in terms of (usually) positive correlations between the time values of successive cycles and groups of cycles. The nature and the degree of these correlations depend on the performance characteristics of the individual worker and often vary for the same worker under different circumstances.

These results can readily be shown to be the statistical reflection of the way in which individual workers plan, organize, and regulate output at the cycle level to meet their financial and other external needs and to fit their capabilities. As a simple example of why correlations arise, workers frequently accelerate their production pace when they fall behind their quotas and reduce their pace when they are ahead of the quotas. These quotas, it might be added, are usually self-imposed within the restrictions established informally by the worker group.

At the element level, where relatively large cycle subdivisions are considered, significant correlations again were almost always found to exist. These correlations showed that the elements in an operation cycle are not independent entities but are connected by a highly complicated network of relationships. These relationships are unique to individual workers and may vary for the same worker under different operating situations.

Thus, these correlations are the statistical reflection of the method and pace with which a worker will produce each item, and arise because the worker organizes his performance characteristics into an integrated pattern. The primary factors involved are again the worker's abilities and needs but with a change in emphasis from financial and other external needs to more subtle physiological needs.

Some of the specific ways that planning and organization take place are:

(1) a prolonged delay in one part of the cycle prompts the worker to exceed his usual pace in a later part of the cycle;

(2) Workers differ in the number, the type, and the duration of delays encountered;

(3) workers vary the way they perform certain elements;

(4) many workers introduce extraneous elements into their work methods from time to time.

In almost all cases, the specific nature of these performance characteristics is unique to the individual worker.

These findings were confirmed by a series of studies comparing the element structures of workers on the same operation. It was found that the average time values for the elements were never (statistically) equivalent for two or more operators. Also, the consistency with which these elements were performed were only occasionally equivalent. Essentially the same conclusions were reached with respect to element groups, which were made up of groups of elements in such a way as to produce the mutual independence necessary to permit them to be considered individually.

In fact, grouping elements in this manner makes it almost impossible to find subdivisions in the element structures of two or more operations which are even descriptively comparable. Thus, operation elements are organized so uniquely by individual workers that the grouping process practically destroys the possibility of finding the same subdivisions for other workers, let alone for other operations.

A parallel set of studies was made on the so-called fundamental motions involved in certain laboratory and factory operations. These studies showed that the motions in an operation are also connected by a highly complicated network of relationships unique to the individual worker. In fact, the motion structure is even more closely related to the worker than is the element structure, with the pattern of relationships among motions often changing after a short time even for the same worker.

When the motions were combined into motion groups, the results were similar to those observed at the element level. Most of the motion groups that were developed did have the property of independence necessary to consider them in an additive manner. However, these groups are so unique to the individual worker that they can rarely be found in the motion structure of any other operator, let alone of any other operation.

It was also observed that each worker's motion (and element) structure can be broken down into two distinct components. The first can be defined as the expected, relatively constant, and usual mo-

OPERATIONS RESEARCH

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tion pattern, including a set of relatively fixed relationships among the motions. When a special situation arises, however, such as difficulty in engaging moving parts, the worker uses another motion pattern. This can be defined as the unexpected, varying and occasional motion pattern, in which the relationship among the motions is also changed. The nature of the occasional motion pattern depends on the nature of the situation encountered and on the worker's adjustment to it.

Studies were also made at the cycle, element, and motion levels on the average performance times and their degree of consistency. At the cycle level, workers on the same operation were found to have widely different mean times, which can be attributed to their different abilities, needs, and purposes. At the same level, however, these workers were found to have approximately the same degree of consistency. This can be attributed to their common use of work methods with similar gross characteristics. Additional support for this hypothesis is the fact that inexperienced workers reached the consistency of performance of experienced workers well before they reached the mean level of experienced workers.

At the element level, workers were found to differ not only with regard to mean times but also with regard to consistency in many cases. Thus, the similarity of their work methods did not extend to elements. Differences among workers were found to be even more pronounced at the relatively minute motion level with respect to both mean times and consistency.

Implications Regarding Element and Motion Definitions

These findings have fundamental and far-reaching implications regarding standard-data theory and practice; these are described in detail elsewhere. [12] They have equally important implications regarding the theory and practice of work methods. In particular, using the time parameter as a measurement base revealed certain fundamental facts which probably could not have been discovered by qualitative empirical observation alone.

The first major implication is that descriptive definitions are not sufficient to describe elements adequately. In the motion case, the definitions are even more inadequate largely because of the widespread belief that there exists only a limited number of so-called fundamental motions. As the preceding evidence shows, a limited number of descriptive definitions cannot possibly encompass all the motions encountered in industrial operations. Elton Mayo puts the matter well in a discussion of industrial fatigue. [13] "It is too fatally easy," he says, "to conclude that because we have a word ('fatigue' in his case) there must be a simple thing or fact that corresponds with it."

This situation has been recognized to a limited extent by certain writers. Thus, Gillespie suggests that the ordinary definitions be expanded so that the path, direction and extent of motions be recorded, as well as the distance and body posture used. [14] Fairchild also found the usual motion descriptions inadequate for analyzing certain light machine-shop operations requiring great skill. [15] This prompted her to develop a set of "skill-factors," such as sensitive eyes, and so forth, to supplement the usual motion definitions in connection with these operations.

Although they make the motion descriptions more nearly definitive, the classifications recommended by these writers are far from exhaustive. As indicated above, the motion patterns of workers will differ in an almost infinite number of ways. This means that the process of descriptive definition would have to be extended indefinitely to cover all the motion variations existing in industrial work.

No matter how carefully made, then, a descriptive definition will never be completely satisfactory. To identify a motion sharply and uniquely, it is also necessary to state its chief statistical properties, such as its mean value and the standard deviation value.

Other Implications Regarding "The One Best Way" Concept

The experimental findings presented above also make clear that movements are not independent of one another nor of the sequence in which they are found. Hence, rearranging motions or elements, according to the "one best way" approach, will produce an entirely new motion or element structure with totally changed properties. It is also clear from these findings that the properties of elements and motions are not essentially constant among workers or even for the same worker.

The "one best way" assumption that motions and elements are independent and have essentially constant properties is needed to justify the further assumption that "the one best way" should be free of unproductive movements. However, it has conclusively been shown that there is a vital interdependence among motions and elements which is unique to individual workers. Consequently, the latter assumption cannot be valid and it follows that a work method devoid of all unproductive movements is not necessarily superior to one with some unproductive movements. Thus, the interposition of a pause, say, between certain element groups might help achieve a balance and a stability of the element structure and, hence, serve a subtle but significant productive function.

The experimental findings summarized above provide considerable direct evidence bearing on this subject. To review just one, workers exhibit an unexpected, varying, and occasional motion pattern to cope with special situations. For example, a worker finding difficulty with a partially-completed assembly might disassemble it and make a fresh start so as to avoid the difficulty. The disassembly is an unproductive element in the "one best way" framework but it is clearly productive in the sense that it permits an easier and/or faster assembly under the given conditions.

The experimental findings also makes clear that it will be impossible to abstract a "one best way" or even an optimal work method on the basis of an extremely limited number of observations and on arbitrarily selected workers. This procedure does not reveal nor does it take into account the variability of capacities, needs, and purposes of different workers and how it affects their work methods and their production performance. Also, the observation process makes substantial use of the observer's subjective judgment and, more generally meets the rules of scientific inference in no important detail.

This is additional and confirmatory evidence that the "one best way" concept has at best only a gross and superficial relation to actual work methods. It is actually little more than an arbitrary and simple-minded postulate of work methods: it expresses a generalized value judgment regarding how work should be done if work methods *were* actually made up fixed, immutable, and universal subdivisions with fixed and immutable properties.

The Framework of a Theory

It has clearly been established that purposive human attitudes and behavior critically affect work methods and effectively destroy any possibility of realizing a "one best way" except in a superficial and gross sense. This effect could be minimized only if workers could be prevented from planning and organizing their work activities so as to optimize their results in terms of their capabilities, needs, and purposes. Assuming this were possible, independent elements and motions with essentially fixed properties could then be obtained to make "the one best way" (and standard-data) concepts realizable. But this result would be gained only at the expense of reducing the worker to a non-purposive being, at least at the work place.

It turns out that this is not only socially undesirable; it is also technologically undesirable. Sufficient evidence of this is given by the production line of the automatic factory where human workers are replaced by mechanical workers. Here, the designers of the mechanical workers found it necessary to introduce purposiveness into their behavior in order to be able to run such a factory at all. In fact, the only technical barrier to complete mechanization in many industries is the inability to reproduce the purposive human behavior sufficiently well to remove human workers from the production line.

This analogy suggests that human purposive behavior at the workplace is likewise necessary for effective work performance. What is needed, then, is to bring the worker and his task into an

optimal relationship in which full advantage is taken of his ability to plan and organize his activities. The problem, then, is to optimize production effectiveness, i. e., to obtain the maximum possible amount of production output under the restriction that the workers' vocational and social welfare not be impaired. To achieve this, it will be necessary to permit workers some latitude in exercising their purposive abilities. The methods engineer's function, then, is to set broad boundaries on the workers' activities rather than to specify them in microscopic detail. An immediate consequence of this is that much more attention should be paid to what the workers bring to the work place in terms of abilities, needs, and purposes.

To formulate the framework of a theory of work methods at the intra-cycle level, it is quite useful to examine some results of experimental work at the inter-cycle level. In particular, considerable experimental work has been done on the effect of varying work activities on a regular basis. [16] In essence, this work indicates that, within broad limits, changes in task, rest periods, and breaking the work load down into small self-contained lots relieve the workers from the undesirable physiological, psychological and other consequences of uniformity of task, in part because it gives him a periodic sense of accomplishment. These devices have also led to a frequently substantial increase in production output, at no apparent cost in terms of the worker's welfare.

In a vital sense, these three varieties of changing the task correspond to certain intra-cycle phenomena reported here. In the latter case, the changes of task become changes in work methods; rest periods become the deliberate employment of pauses and delays; and the small lots become the element (or motion) groups. It seems reasonable, then, that workers adopt these devices in part to relieve themselves of the consequences of uniformity in work. More than that, these devices enable the worker to fit his capabilities, needs, and purposes to the requirements of the task. Thus, rather than being unproductive, pauses, changes in work method, and so forth may actually be required by the worker to perform in a manner that he finds optimal.

Since these worker devices with regard to intra-cycle work methods are parallel to the changes of task and rest pauses at the inter-cycle level, it is reasonable to suppose that they may yield the same beneficial results, if properly controlled. Under this hypothesis, it follows that workers may produce more in the long run by using certain extraneous motions and elements than by attempting to adhere to a method in which such elements and motions are eliminated.

It would seem advantageous, therefore, to introduce certain extraneous motions and elements into the systematic work method adopted for an operation. This would require specific studies to determine which extraneous elements and motions, including delays, are used in specific types of operations, in particular those which increase productive effectiveness, e.g., by increasing output or by simplifying the worker's task. To repeat an example given above, an intentional pause, might be introduced between two element groups in order to obtain a balanced and stable relationship among the element groups.

In addition, specific studies should be made at the local plant and industry level on how motions and elements might be combined into interrelated groups in such a way as to lead to greater production effectiveness. The combination of motion groups and element groups, like those considered in this paper, which have a functional unity would be an important component of this process. Thus, it might be discovered that the first three elements, the second two elements, and the last three elements of an eight-element operation grouped as indicated might result in an optimal production effectiveness for most workers assigned to that operation. In this connection, it might be mentioned that the most productive workers observed in the studies summarized above invariably organized their elements and motions into unique groupings within which there was a *high* degree of correlation.

The experimental findings also indicate that it might be well to incorporate two components into the systematic work method adopted: (1) the basic method, including certain stipulated relationships and groupings as well as interposed "extraneous" motions and elements, for the typical and expected work situation, (2) the supplementary method intended for special situations arising unexpectedly and occasionally. It is worth repeating that the methods engineer's function is to set up boundary conditions rather than to specify either the basic or the supplementary method in detail. In particular, he should guide the worker's purposive behavior so that, say, obviously poor work methods are eliminated. He should otherwise give the worker the opportunity to plan his activities in a manner optimal to him.

The most important and the most formidable problem, then, is that of formulating criteria for deciding how much of the work method shall be standardized and how much should be left to the worker's discretion and choice. These optimization criteria, it should be noted, will depend on the peculiar characteristics and requirements of the individual plant, its working force, and its management.

Such criteria might well be developed using a methodological approach suggested by statistical quality control theory; this has successfully been applied to the problem of determining when an operation can be considered standardized at the cycle level. [17] An extension of the same approach to the intra-cycle work methods problem should be equally fruitful, using as a base the suggestive hypothesis that consistency of performance is more closely related to work methods than is level of performance.

It must not be expected, however, that a theory of factual generalizations can be developed for work methods in the same sense, as a natural science, where one has, say, the laws of thermodynamics. One of the major difficulties in current work methods (and work measurement) practice is that it is erroneously assumed that such generalizations can be made. The result is that generalizations have been enunciated with little or no empirical validity.

The experimental findings presented above make it quite clear that a meaningful theory of work methods must be a procedural theory presenting primarily a methodological approach. This approach will show how procedures and criteria can be developed to fit local situations. It cannot give specific procedures and criteria that have universal validity even for a single industry.

This puts a much greater burden on the individual methods engineer than on, say, mechanical engineers, for there will be no handbooks in which to find constants and equations. They will have to develop their own handbooks, and the handbooks will contain neither constants nor equations. It has been the purpose of this paper to present a framework for the required procedural theory and to indicate the direction along which the handbooks might be developed.

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Attitudes and Productivity

By Guy B. Arthur, Jr.
Guy Arthur and Associates, Inc.

Many incentive systems and plans are never fully effective because the attitude of employees is bad. That is one reason why the same incentive plan brings about great savings in one department or plant but fails to accomplish the similar results in another department or plant.

While many industrial engineers agree with this contention very little research work has been done on the problem. It would appear from some of our findings that a study of attitudes should be a prerequisite to the installation of (or revision of) any incentive plan. As an example, most incentive plans are based upon job evaluation. If the employees do not have confidence in the job evaluation plan because they do not understand it or they think the plan is unfair, they will not have confidence in any incentive plan based upon said job evaluation. Still our surveys show that far too many employees either do not understand how their job was evaluated or they feel the job evaluation is unfair.

FEAR

Employees who do not trust their management will never exceed a certain productivity per man hour because they fear the rates or standards will be tightened up. Still we all know that people with unusual skills or abilities can produce twice and sometimes three times as much as a normal person. I recall in the mid-thirties when I was asked to check the exorbitant production of one girl. The people in her plant did not hesitate to produce their maximum because they had confidence that management would not cut their rates. This girl consistently produced fifty percent more than the next best girls on the operation—and these next best girls were turning out thirty-three percent more than the average girls.

Her motions were so fast, that from a stop watch study, we could develop no reasons as to how she did so well. Still, it was very important to determine the secret of her success; because, if possible, we wanted to teach the other operators the same skill. That would increase their earnings and reduce our clients' costs. We resorted to a motion picture study of these girls and in turn analyzed their motions with the projector running very slowly. For the first time it became apparent that the difference between the best girl and the next best ones was in the pickup phase of the cycle. Detailed study then brought out the fact that the best girl had a twisted thumb which enabled her to grasp the particular part in a fraction of the time that it took even the next best girls. On the basis of this study everyone agreed that the standard for the job was satisfactory and that this girl's skill could not be transmitted to the other operators—short of breaking and twisting a lot of thumbs.

This story is told to point out the lengths to which a few companies will go for the purpose of justifying a rate or standard. Observation indicates that too many companies would have cut that standard because of the very high earnings of one girl. But in the company cited the operators knew that management would not cut their standards. The result was that productivity per man-hour was extremely high in all departments and production costs were very low. How different from many firms where we have made surveys. In some of them, the lack of confidence in management goes back to some management decision made many years ago—quite often to some prior management group. In other cases, this absence of confidence can be traced to a lack of understanding—about the company's objectives, plans or policies.

CONFIDENCE

Certainly employees must have confidence in management before any incentive plan will bring about maximum results. If you accept this theory, why is it then not best to determine the degree of confidence in management prior to installing or revising an incentive plan? Not for the purpose of deciding whether or not to make the change but rather to determine how to develop maximum confidence in advance so that the greatest possible returns will be had from the investment in the incentive plan.

In many employee opinion surveys we ask employees whether or not everyone in their department is carrying their share of the work load. In others we ask whether or not work is distributed fairly among employees. In some departments the majority of responses are in the affirmative. In others, very few, (if any) of the employees believe that everyone carries their share of the load or that work is distributed fairly. Obviously a lot of work has to be done in these departments before any incentive systems should be applied. Until employees feel that work loads will be fairly uniform they are not apt to do their best under any plan.

SUPERVISION

Employees usually attribute unequal work loads to their department head or foreman. However, that is not their biggest complaint insofar as their boss is concerned. They want to know how they stand with their boss and most of the time this desire is not satisfied at all. Quite often, an honest and constructive discussion between a boss and an employee will do much to improve his production far more than merely giving him financial incentive. We can all recall many instances where time studies have shown that employees have only been producing two-thirds of what should be normal output per man hour. Incentive systems provide these people with no more money until they exceed the standard. This is a big jump for most people and many installations have failed because the employees never got their hands on enough premium money to warrant additional effort. How much better it would be if the reasons behind employees low performance were ferreted out and corrected prior to the application of incentives. These reasons may be physical (tools, layout, handling, jigs, etc.) but they may also be attitudes regarding the company or the supervisors.

Attitudes and opinions can be changed although it is not as easy as improving floor layout or a jig. The similarity in making the change ends after the first step which is to locate the trouble. In both cases you have to make a study to determine what is wrong or what needs to be changed. Our business is that of studying employee opinions to determine where they are below standard and what can be done to improve them.

OBJECTIVE

Our first approach is to determine what management is after. Is their objective to learn how they can improve communications and bring about better understanding; how to improve supervision and improve employee relations; or to determine what is keeping employees from putting forth their best efforts? Once we agree upon an objective we then submit a proposed set of questions which our experience indicates will bring forth constructive answers. Such questions must be understood by the employees in question and for that reason we check them carefully against readability formulas and minimum vocabularies. The questions must be reliable so we check them against our reliability averages to be sure that we obtain good dispersion of answers. The questions are designed to force employees to give us a positive or negative answer. If this is not done, a majority of them (being human) will take the easy middle course which is of little value. A conference between management and ourselves brings agreement as to the questions we are to use. Usually these are a modification of those we proposed but they still meet our stan-

(Continued on Page 23)

Fitting Curves To Timestudy Data

By Fred H. Lambrou

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As Industrial Engineers we emphasize using the proper tools for the particular job, but often do not apply this rule when doing our own job.

In timestudy work we gather data for analysis but often extend our judgment beyond the limits that we should. By this I do not mean that we can eliminate leveling and rating. What I am saying is that we can often use statistics to show us the risk we are taking and also see how reliable our results can be with the data we have.

The word statistics often frightens many people into not using them. This of course should not be so, because the computations are often simpler than those which the timestudy man usually performs in his daily routine.

Below I will endeavor to show how a timestudy man can check his standard data curve using correlation methods. The theory will not be discussed here but the steps and methods used will be discussed and illustrated.

When the timestudy man is developing a standard data curve there are usually two variables involved; the independent variable which can be weight, length, area, volume, size, or any other physical characteristic and the dependent variable which is usually a unit of time such as hundredths of a minute. There is of course a correlation between the dependent and the independent variable, and how strong this degree of association is between the two variables is what we want to determine.

Statisticians use the coefficient of correlation as a measure. This will be denoted by R. When all the points plotted are on the curve this is called perfect correlation and R will be 1 when there is a direct relationship between the dependent and the independent variable and -1 when there is inverse relationship. This of course is the ideal condition but usually not the case. Since points will be scattered on either side of the curve we want to determine how close we are to perfect correlation. Therefore the closer R approaches 1 the better the correlation between the two variables.

$$R = \sqrt{1 - (A/B)}$$

Step 1. Plot points on graph (Fig. 1).

Step 2. Draw in curve (Fig. 2).

Step 3. Measure off distances from points to curve (Fig 3).

Step 4. Square distances (See Fig. 4).

Step 5. Sum up squares and divide by the number of readings. This is A or $A = \Sigma(Y - Y_c)^2/N$

Step 6. $B = g - h = [(\Sigma Y^2/N) - (\Sigma Y/N)^2]$ To find B take the dependent variable (time) and do the following:

(a) Square each reading.
(b) Add the squares.
(c) Divide by the number of readings. You now have g or $g = \Sigma Y^2/N$
(d) Add all the readings.
(e) Divide by the number of readings.
(f) Square the answer. You now have h or $h = (\Sigma Y/N)^2$
(g) Substitute g—h and obtain B.

Step 7. Substitute A and B in above equation and you have the answer.
Now if you like the formula in a compact form it becomes:

$$R = \sqrt{1 - \frac{\Sigma(Y - Y_c)^2/N}{(\Sigma Y^2/N) - (\Sigma Y/N)^2}}$$

Following is an illustration of a typical curve that will be used to show the relative ease that this information can be obtained. The steps are given which the timestudy man will usually go through in obtaining the coefficient of correlation.

Given:

Length in Inches 1 2 3 4 5 6 7 8 9 10

Time in Minutes .02 .015 .025 .055 .065 .06 .07 .105 .095 .11

Step 1. Plot time in minutes against length in inches (See Fig 1).

Step 2. Draw in line (See Fig. 2).

Step 3. Measure distances of points from line (See Fig. 3).

Step 4. Set up table (See Fig. 4).

Step 5. Make computations as follows:

We said $R = \sqrt{1 - (A/B)}$

and $A = \Sigma(Y - Y_c)^2/N$
$= .000975/10 = .0000975$

and $B = (\Sigma Y^2/N) - (\Sigma Y/N)^2$
$= (.04905/10) - (.62/10)^2$
$= .004905 - .003844 = .00161$

$$R = \sqrt{1 - \frac{.0000975}{.00161}}$$

$$= \sqrt{1 - .0919} = \sqrt{.9081}$$

$$= .953$$

The coefficient of correlation is .953. Perfect correlation would be exactly 1.0 but since all points are not on the curve the coefficient is something less than unity. In timestudy work I have found when the correlation coefficient is between .95 and 1.0 good correlation exists and the line could be considered adequate; a correlation coefficient between .90 and .95 was fairly good, between .80 and .90 there would have to be a review of the data and a consideration of the accuracy desired.

This technique will give the timestudy engineer a yardstick with which to measure his results and to determine their suitability for the uses to which they will be put.

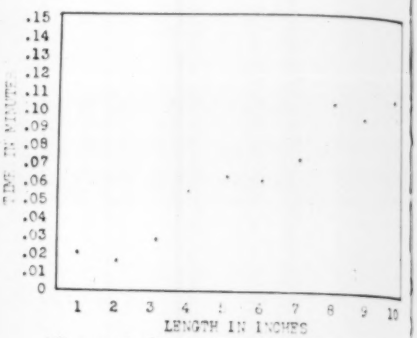

Figure 1. Draw Scatter Diagram (Plot Points).

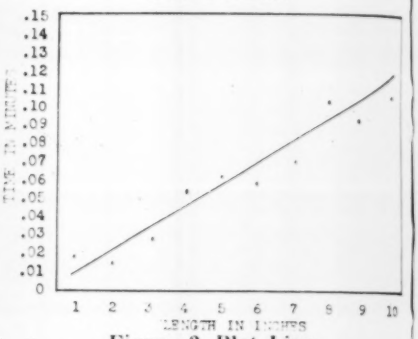

Figure 2. Plot Line.

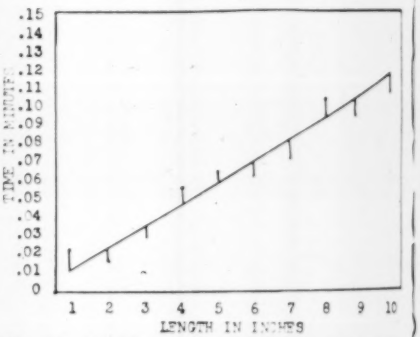

Figure 3. Measure Distance of Points From Line ($Y - Y_c$).

X Length in Inches	Y Time in Minutes	Y^2	$Y - Y_c$	$(Y - Y_c)^2$
1	.02	.0004	.01	.0001
2	.015	.000225	.005	.000025
3	.025	.000625	.01	.0001
4	.055	.003025	.01	.0001
5	.065	.004125	.005	.000025
6	.06	.0036	.01	.0001
7	.07	.0049	.01	.0001
8	.105	.011025	.01	.0001
9	.095	.009025	.015	.000225
10	.11	.0121	.01	.0001
Sum	.62	.04905		.000975

Figure 4. Working Table for Calculation

BOOK REVIEWS

"Fabricated Materials and Parts"
by Theodore C. DuMond,
Reinhold Publishing Company,
New York, 1953, 332 pages, $6.50

This is one of the best compilations of the advantages and limitations of manufacturing processes which the reviewer has seen in recent years. The discussion of each process is complete, yet not long. Some cost and production volume data is included, but not enough to impair the usefulness of the book as prices change. The author covers all the common processes plus such useful but little discussed methods as sectioned tubing and such recent developments as electroformed parts. This is an excellent reference volume for the industrial engineer whose work requires knowledge of the merits, cost factors, and disadvantages of various manufacturing processes.

"Handbook of Standard Time Data"
by Arthur A. Hadden and
Victor A. Genger
The Ronald Press Company,
New York, 1954, 473 pages, $10.00

This handbook contains a wealth of standard time data for metal working machine tools. The tables emphasize recommended speeds, feeds and depths of cut in arriving at standard time values for basic machining operations. Separate tables show times for set-up and handling operations. The basic metal-working machine tools, arc welding, punch press work and assembly operations are covered. Unlike the commonly used predetermined time systems, times are shown only for complete handling elements and machine operation operating cycles. There is no breakdown into elemental motions.

The authors have collected this material during twenty-five years of consulting practice in the metal working field. Unfortunately, they do not furnish information on how the data were computed and the statistical variability inherent in the figures. Thus, the industrial engineer will have to judge the usefulness of the time values in his own plant, using his own training in motion and time study. Even if the time standards cannot be used directly, they may serve as a guide in the evaluation of present and proposed methods and time standards. The tabulations of machine feeds, speeds and times will be quite useful, even though the manual times are inapplicable.

The authors recognize that no time standards such as they propose are generally applicable without some modification. They say, "Conditions in different plants are variable and these differences must be recognized." The industrial engineer using this handbook must study the applicability of the data to his own plant and make any changes necessary.

"Motivation and Morale in Industry"
by Morris S. Viteles
W. W. Norton & Co., Inc.
New York, 1953, 510 pages, $9.50

The social sciences are giving a new concept of the sources of motivation that determine morale in industry. A comprehensive description and critical evaluation of the principal experimental studies and surveys that form this new approach is the subject matter of Dr. Viteles' readable book. In it he shows that the financial incentive, as embodied in the piece work and similar systems, as the one driving force to induce employees to increase productivity is being replaced by a recognition and understanding of the complex nature of human motives.

Though Dr. Viteles uses the findings of social psychology as a point of departure, the bulk of the book describes and evaluates experimental work in industry and the application of these findings by management today. The book is not only useful in acquainting the reader with the extensive work illuminating employee motivation and morale, but the bibliography and notes are encyclopedic and will act as a basic source book for further study. It is the first time such a wide range of material, generally not available in the regular literature, has been brought together in one volume.

Viteles states the continuing need in industry is to increase production, to promote employee satisfaction and adjustment at work and to curtail industrial strife. The emphasis of the book is on the application of the findings and as such is a useful and practical book for management in raising the level of production and insuring the morale of the industrial employee.

Reviewed by: Alan J. Levy, Bulova Watch Company

"Seminar on Operations Research, Proceedings"

Sponsored by the Railway Systems and Procedures Association, with Technical Assistance from Operations Research Office, the Johns Hopkins University. (Order from Mr. J. W. Milliken, 30 Church Street, New York 7) 1954, 131 pages, $4.50.

Proceedings of a meeting specifically intended to highlight the applications and possible applications of Operations Research in the railway industry. The presentations will be of interest to those looking for further information on the nature and use of Operations Research. Topic headings are: Operations Research in Industry; The Value of Operations Research to the Army; Operations Research as a Tool for Railway Management; Analysis of a Classification Yard Operation; Information Handling in Business Operations, Analysis of Maintenance-of-way Problems; Research Team Approach to an Inspection Operation; Information for Overall Company Planning Through Operations Research; A Systems Approach to Rail-truck Coordination; An Operations Research Approach to Railway Rolling Stock Requirements; and Organization, Selection and Training of an Operations Research Group.

"Psychology of Personnel in Business and Industry"
by Rogers M. Bellows
Second Edition,
Prentice-Hall, Inc.,
1954, 467 pages, $7.35

Psychology and personnel relationships are acquiring more and more importance in the work of industrial engineers. Since most of the industrial engineering training must of necessity concentrate on general and industrial engineering principles, the practicing IE may want a book to increase his background knowledge of this important field. If he does, Bellow's volume will be helpful since it is quite readable, reasonably complete and well referenced for additional investigation. He emphasizes individual and group employee psychological patterns and the selection and training of workers.

"The Closed Die Forging Process"
by P. E. Kyle,
The Macmillan Company,
New York, 1954, 128 pages, $1.50

There are relatively few books available which cover only one manufacturing process. The market is generally too limited for the effort involved and it is difficult to keep the material from being quickly outdated. Perhaps the solution is a series of shorter volumes such as Dr. Kyle has written. He covers the mechanics and engineering characteristics of the forging process briefly but very well. The book is profusely illustrated and discusses the main points the average engineer needs to know about the closed die forging process.

"Welding Processes and Procedures"
by Joe L. Morris,
Prentice-Hall, Inc.,
New York, 1954, 255 pages, $5.00

The author is to be commended for the excellent job he has done in combining engineering and metallurgy with the mechanical details of welding processes. He covers the major welding processes quite adequately using descriptions and illustrations without extending the discussion unnecessarily. The welding characteristics of commercially used materials, testing, welding design, oxygen cutting, and relative costs are also discussed. The industrial engineer who needs a welding reference which is not too detailed will find this volume worthwhile.

READING AND WRITING

(Continued from Page 5)

definition of a hard word oversimplified is one of three syllables or more. (See page 36 for the modifications)

Similarly, Rudolph Flesch sets up one standard as 17 words average sentence length. With this goes an average syllable count of 147 per 100 words. This he places against 8th. and 9th. grade understanding and estimates that it applies to 83 percent of U. S. adults.[10] He goes on to point out what it is that makes Reader's Digest interesting to read. He comes out with a count of personal words of 7 percent and of personal sentences as 15 percent. To get the count of personal words, Flesch says,[11] "Count all personal names in your text. Then count all personal pronouns (except the *its* and *theys* that don't refer to people). Next, count all masculine and feminine words like *uncle* or *spinster* (but not masculine or femwords. The percent of hard words is seven. The total of these two counts is 22 (15 plus 7). This he multiplies by .4 to arrive at his fog index of nine. His inine words like *teacher* or *employee*). Finally, for good measure, count the two words *people* and *folks*."

Personal sentences Flesch describes[12] by calling them conversational sentences. He says, "After all, these questions, exclamations, and commands are really nothing but a one-sided conversational exchange between author and reader." The count of these is added to that of sentences of spoken dialogue in order to get the total.

[10]Flesch, Rudolph, **Art of Readable Writing**, Harper & Brothers, New York 1949, p. 149.
[11]Loc Cit, p. 68.
[12]Loc Cit, p. 79.

PROFESSIONAL DIRECTORY

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You will be interested as an engineer to see how he uses alignment charts to figure out his scores for interest and readability.

Report Writing

Most of us write reports more often than we turn out articles or books. Yet we can improve these too. "Let's Take The Straight Jacket Off Technical Style," says Robert L. Shurter in Mechanical Engineering, August 1952. He says, "Engineers can begin to break this strait jacket by doing two simple things.

1. Start using personal pronouns.
2. Write in the active voice instead of the passive.

Again, there is more involved than style alone. For example, I was taught to put a "letter of transmittal" on top of a long report. But I never appraised a railroad system. My reports are short. Most of yours are too. Even so, the idea is good. The "letter of transmittal" was to give all of the major facts, conclusions and recommendations in concise form.

Following the same idea in a short report, your first paragraph might contain three sentences. Your first can state or recall why your report was prepared. If you are replying to an inquiry, you might start off with something like, "You asked me to find out something." You may say when by giving the date he asked you. This is desirable if some time has elapsed since the request was made. On the other hand, if you initiate the report, you might start off with something like, "I think you should know that so and so is the case."

Your second sentence may contain the gist of the facts that you have. Your third sentence would contain your conclusions or recommendations.

In this way, you give the boss what he needs to know in short order. He can read on to get more details if he wants them. Get out the essence—your main points first—and explain later as I tried to point out to the author whose paper I blue penciled.

The need for gaining attention at the start, I think you recognize. But not everyone sees in advance that he must come to a conclusion. I remember Don Copell's reaction to a speech we heard one time. When I asked, "What do you think?" Don replied, "He had a half a dozen good places where he could have stopped and passed up every one of them."

PRESIDENT'S MESSAGE

(Continued from Page 2)

analysis, Industrial Engineering is in a excellent position to contribute to the growth of the engineering profession as a whole. It becomes our duty to delineate adequately these facets of our approach to the engineering family. The activities and publications of our society and individual members will thus help to provide the public with a more comprehensive operational definition of the Engineering profession.

We shall make every effort to continue and expand our "extra-mural" activities.

The second theme, "Industrial Engineering at its Cross-Roads," a theme proffered by Editor Bob Lehrer, also deserves much serious thought. Where is Industrial Engineering going? What is its future? are the questions asked. Over a period of time Industrial Engineering is essentially defined in our practical world by the articles that appear in the Journal, by the activities of those who are members of AIIE and others that permit the title of Industrial Engineering to describe their professional activities, and by the curricula and course content of Industrial Engineering as it is taught in colleges and universities.

The above tends to provide an "historical" or "experimental" definition of Industrial Engineering. While such information is valuable, it fails to provide adequate means for predicting future growth. Before this can be done, the unique objectives of the field must be determined and agreed upon. I propose that we give serious thought to the development of an adequate definition of the long run objectives and problem-solving area of the Industrial Engineering profession. Only by such thought, discussion and eventual agreement may we hope to arrive at a philosophical description of the field and thereby be enabled to grow toward some goal, or standard. This setting of a goal is something we all recognize as an indispensible catalyst to progress.

The process of determining the Industrial Engineering needs in the future and providing curricula adequate to these needs is one of our most important challenges.

Industrial Engineers should continually re-examine the basic design of the systems for which they are responsible. Changes in even the very structure of such systems should be courageously recommended when it becomes evident that such change is necessary to the mutual satisfaction of all interested parties.

I call on each of you to participate in the activities of your Institute. Only by your continued interest and participation will AIIE be meaningful to you and in turn continue its growth.

"Predetermined Standards for Typing—Preliminary Study"
by Harold E. Smalley
University of Connecticut
Storrs, Conn., 1954

An interesting report of the preliminary stages of a project sponsored by the University of Connecticut, M. T. M. Association for Standards and Research, and Bigelow-Sanford Carpet Company to explore the possibilities of developing a set of predetermined motion times for typing activity. The study is introduced by a reasonably complete coverage of the background of clerical standards and the problem of attempting to use predetermined motion time standards for such work. The methods of planning and executing the study are reported in complete detail.

WORK SAMPLING STUDIES

(Continued from Page 12)

pling data and to the application of statistical tests are outlined. It is noted that forecasts based on work-sampling data are subject to the same type of limitations as apply to other methods of work measurement. It is indicated that the results of a series of work-sampling studies may be tested for random variation; that if this variation is not random, analysis of variance or regression analysis may provide estimates of the rates of variation and means of testing the significance of such estimates. In a simple case, tests based on the binomial law are appropriate and the size of sample required can be expressed as a function of the sample proportion and the admissible error and level of probability desired.

Planning a work-sampling study may involve selection of an admissible error. This is a matter of judgment involving the degree of accuracy desired, the cost of securing a given level of accuracy, and the resources available for the study. Since these factors will vary with different situations, no single rule as to the admissible error can be given. Evidently, a criterion that is satisfactory in one situation may be rejected in another. The criteria discussed in this paper—constant absolute error, constant percentage error, and constant sample size— yield different results with respect to standard of accuracy and sample size in relation to the sample proportion. Obviously, many other criteria could be devised, some of which would have special merit for a particular situation.

The graphic relationships presented for the particular accuracy criteria discussed in this paper are a convenient tool for planning work-sampling studies where such criteria are appropriate and may be useful in the development of still other guides to sample design. The charts may also be helpful in judging the accuracy of results from a particular work-sampling study.

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WHAT ARE THE SPECIFICATIONS?

(Continued from Page 7)

ly useful concept or in terms of a scientifically established concept.

2. If we accept the pragmatically empirical criterion, then we discover that almost all pre-determined motion time systems have "worked." The very strength of these systems lies in the residual flexibility left in the systems by their authors. These permit a viable relationship between the workers and the engineers by enabling the engineers to continually re-define their basic data to conform to the workers concept of a fair rate.
3. The imposition of a rigid pre-determined motion time system would take the setting of production standards outside the realm of collective bargaining imposes the obligation upon the engineers to demonstrate the validity of three untenable assumptions.
   a) that there is a scientific level at which workers *ought* to work.
   b) that there is a scientifically tested method for extending this level from one type of operation to another.
   c) that the sub-division of the system constitute a statistically independent set of times which can be combined in any sequence in any configuration.
4. The overwhelming weight of evidence thus far demonstrates that there is no basis for these assumptions.

Lest I appear in the guise of a complete Philistine, let me add that the search for pre-determined motion time systems has led to much valuable study of the detailed mechanics of human motions and the factors that influence their speed. I do wish that the scholarship meat of these investigations was served up with a good deal less selling sauce. The foreigner who views the literature on pre-determined motion times, I suspect, will be more impressed with them as good examples of aggressive American merchandising methods that as guides to sound scholarship.

Correction—May Issue "Plant Investment & Survey Results"

Top of Column One, Page 8; Lines 4-6 should precede Lines 1-3.

". . . which projects can be compared. To use this method, the investment amount is divided by the annual net "profits" to give the number of years in which capital is recovered. As commonly used, no charge or allowance is made for depreciation, interest, or takes in arriving at the profit"

ATTITUDES AND PRODUCTIVITY

(Continued from Page 19)

dards. The questions are then printed on a survey questionnaire form which has been designed to facilitate tabulating for our report.

ADMINISTRATION

Employees in small groups (10 to 15) answer these questions under our actual supervision. This is done to assure complete confidence in the anonymity of the whole survey. It also enables us to bring about complete understanding about each and every question on the part of each employee. As a result, the replies, according to all the research we have done in this area, are valid and reliable. Constant research is showing us how to improve our methods from month to month. This has been going on for seven years and will continue indefinitely. One large corporation is about to enter upon the most extensive research job to date with us in this area of the administration of employee opinion surveys. The importance of administration cannot be overlooked if companies are to have valid and reliable results. Only in this way can they take the right action and avoid doing more harm than good. It is no job for amateurs in the field.

ACTION

Employees deposit their completed questionnaires in locked ballot boxes. The questionnaires are then sent to our office in Toccoa for tabulation and compilation into a report. We do not attempt to analyze the results at this step because we are convinced this should be a joint effort with management who, after all, must take the remedial action. We do put the report in such form that it will be easy for management to understand and use. It is for this reason that all figures are presented in graphical as well as statistical form. These reports are delivered within three weeks of the day we complete the so-called group interviews with employees. Speed is essential at this step in order to get the facts back to management while the survey is still fresh in their minds and of interest. Only then will they take the time to really capitalize on the investment they have made. After management has an opportunity to study the reports we start our series of follow-up visits. The purpose of these is many fold. There are questions to be answered. Reports to supervisors and employees must be made. A plan of action must be developed which lays down the major problems; who will be responsible for correcting same; and when this should be accomplished. In many instances the follow-up by outsiders takes the form of "needling" to assure that management takes action so they will be sure to get a return on their investment in this employee relations tool.